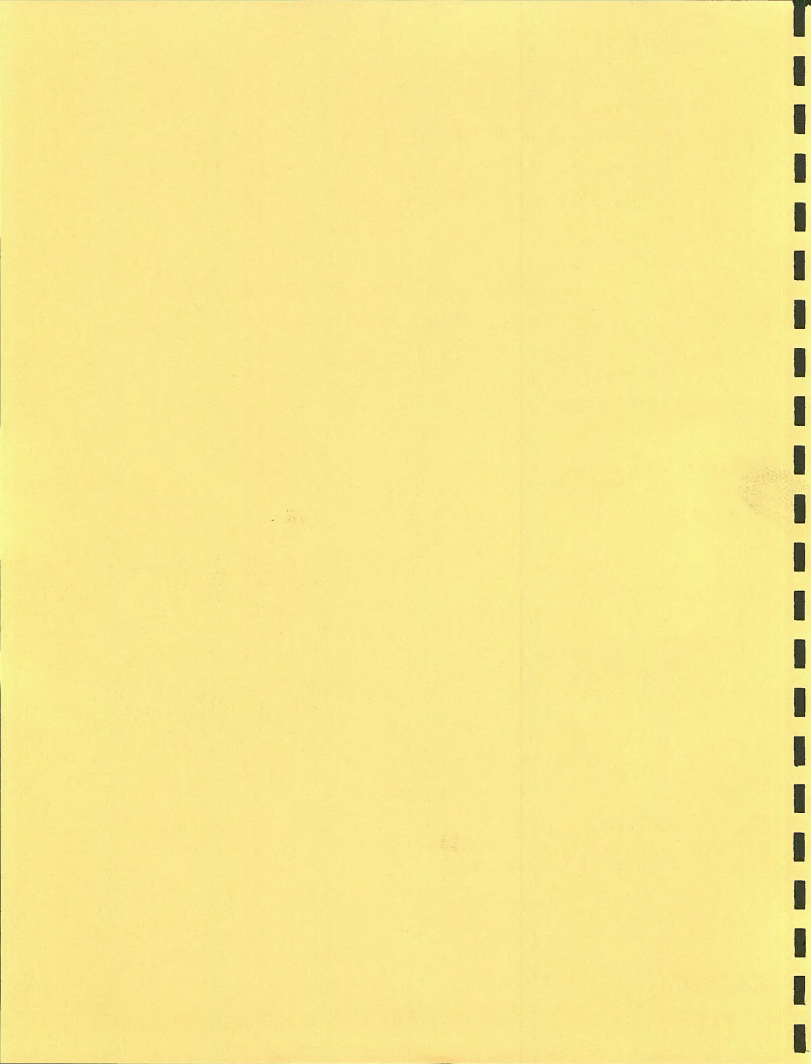A GEOCHEMICAL BASELINE STUDY OF SURFICIAL
MATERIALS IN THE VICINITY OF OIL SHALE TRACT
C-a, RIO BLANCO COUNTY, COLORADO

by

Robert J. Candito

ID 880564445

A Thesis submitted to the Faculty and Board of
Trustees of the Colorado School of Mines in partial
fulfillment of the requirements for the degree of
Master of Science in Geochemistry.

Signed: _Robert J. Candito_
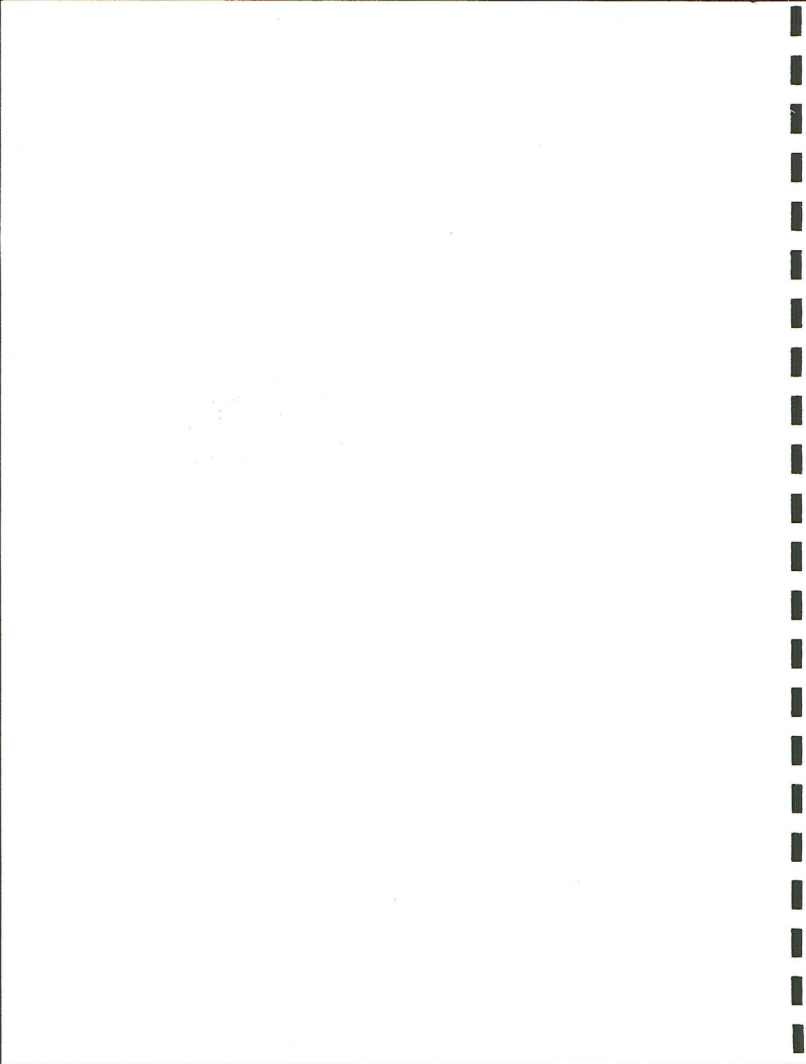Robert J. Candito

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ABSTRACT

A geochemical baseline is being determined for sur-
ficial materials in the vicinity of oil shale tract C-a in
the Piceance Basin of Northwestern Colorado. Two hundred
fifty-three composite samples of A-horizon soils, big sage
(Artemisia tridentata tridentata and subspecies wyomingensis),
rice grass (Oryzopsis hymenoides), and wheat grass (Agropyron
smithii) were collected on a grid eight by six miles.

The elements studied are B, Mo, Zn, Li, As, and Hg.
Concentrations range from crustal averages for Zn, Hg, Mo,
and Li to three to six times the average for B and As. Due
to alkaline conditions these elements may pose special
environmental problems during the development of oil shale
resources.

Analysis of variance techniques were used to determine
those elements that display regional variations. Hypothesis
tests were employed to determine the significance between the
means of components found on the Parachute Creek member of
the Green River Formation and Uinta Formation. Most com-
ponents are substantially enriched in the surficial materials
found on the Parachute Creek member. Regional trends are
displayed in the surficial materials of the Uinta Formation
for several components, thus regional variations are not
caused exclusively by lithologic changes. There are no
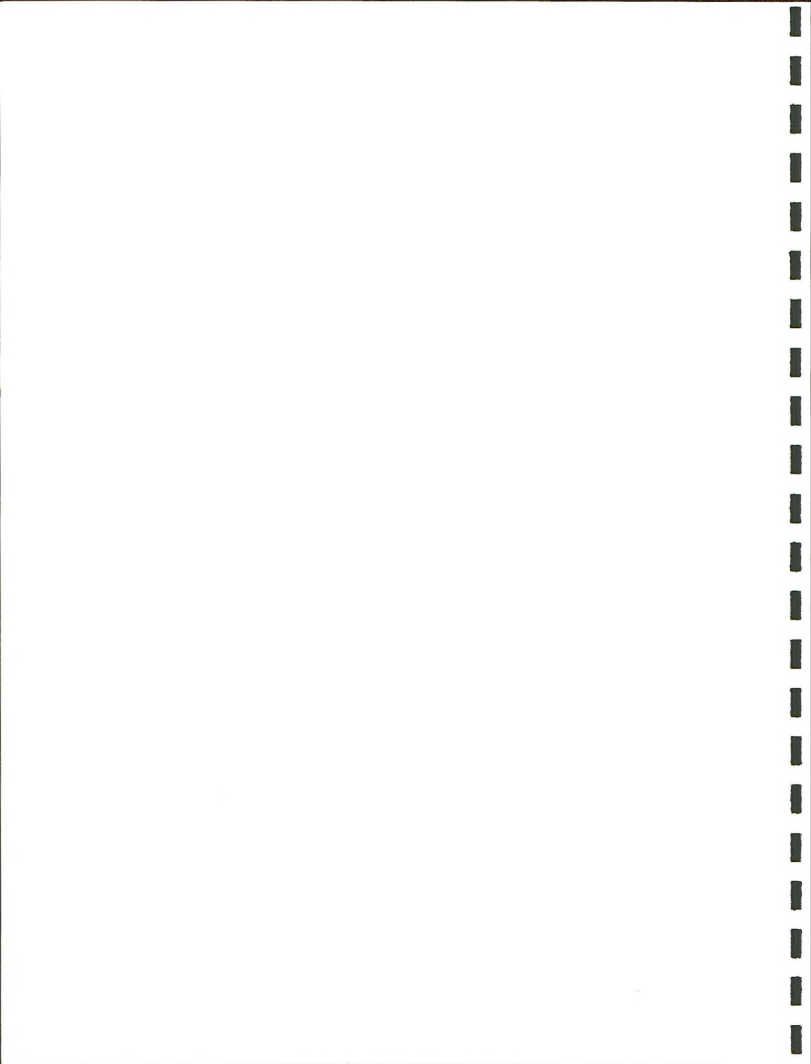
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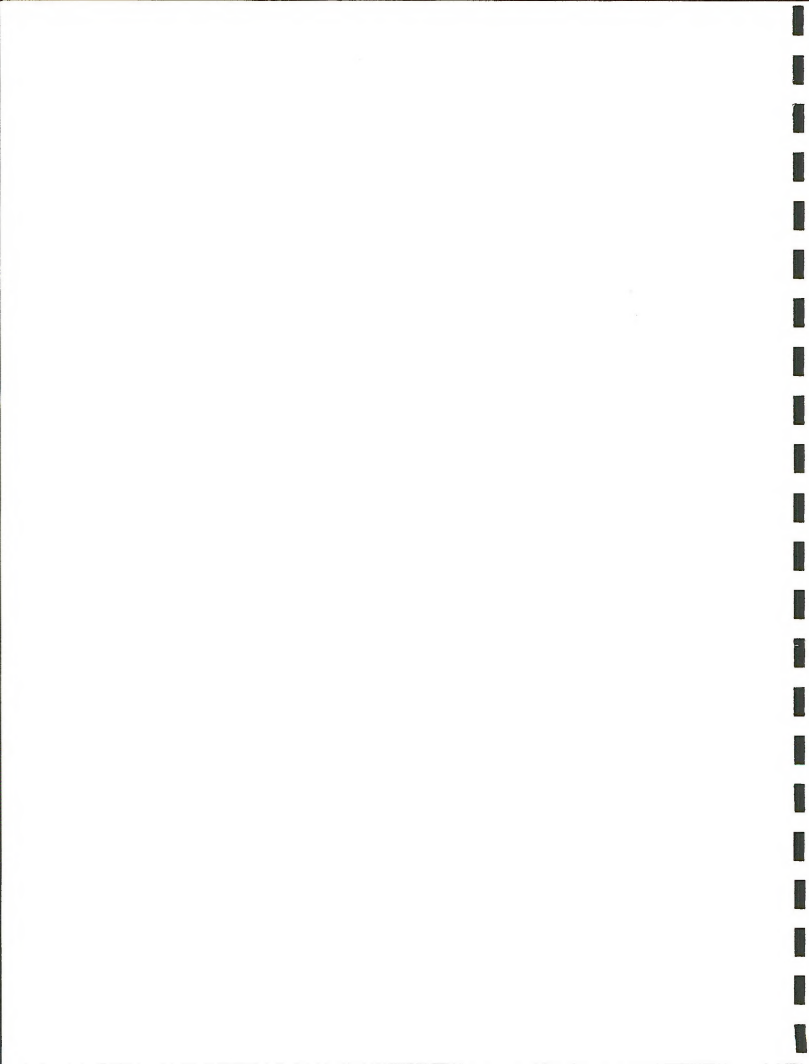
discernible differences between the subspecies of sage for the elements analyzed. Composite sampling reduces low scale variance for elements that show regional trends but local variance is dominant for elements whose distribution is fairly homogeneous.

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INTRODUCTION

The renewed interest in oil shale resources of Colorado has generated concern in the potential environmental impact of surface and in-situ retorts in Colorado, Wyoming, and Utah. Numerous studies are in progress to determine the regional geochemistry of these areas. The chemistry of soils (Klusman and Ringrose, 1976b), streams (McNeal et al, 1976), and plants is studied to establish baselines for future reference in monitoring the effects of the development and environmental impact of the oil shale industry.

Oil shales are fine grained rocks which contain substantial amounts of organic material that can be refined into fuels. The organic material is separated into two fractions. The soluble bitumen fraction makes up 20 percent of the organic material and the remainder exists as a complex insoluble material termed kerogen. The shale oil is obtained by "retorting" the pulverized shale. In the surface operations the rock is subjected to temperatures of $500-550^{\circ}C$. This breaks the chemical bonds holding the organic material to the rock matrix and vaporizes the organic material. It is then condensed into a crude oil that can be refined into final products (Yen and Chilingarian, 1976).

Surface retorting requires the mining and storage of large amounts of rock and waste material. The oil shale available on tract C-a is best obtained by surface mining because of the proximity to the surface of the richest deposits. Southeast from tract C-a, oil shale tract C-b is also being evaluated. On oil shale tract C-b the shale is too deep for economical surface mining so underground or in-situ methods of shale oil extraction are being examined. Both retorting methods produce reducing and alkaline conditions which mobilize many harmful trace elements.

Northwestern Colorado includes parts of the Southern and Middle Rocky Mountains, Wyoming Basin, and Colorado Plateau provinces as defined by Feneman (1931). The area is drained by the Yampa, White, Colorado, and Gunnison Rivers, all of which are westward flowing. The Piceance Basin which contains an estimated 1,200 billion barrels of oil equivalent (Murray and Haun, 1973) is the major structural feature of the Colorado Plateau Province. During the deposition of the sediments in the Piceance Basin the climate was semi-tropical with flora similar to that found now along the Gulf of Mexico (Bradley, 1963). The present climate is semi-arid and has changed the chemical conditions in the sediments making many of the trace elements more easily mobilized.
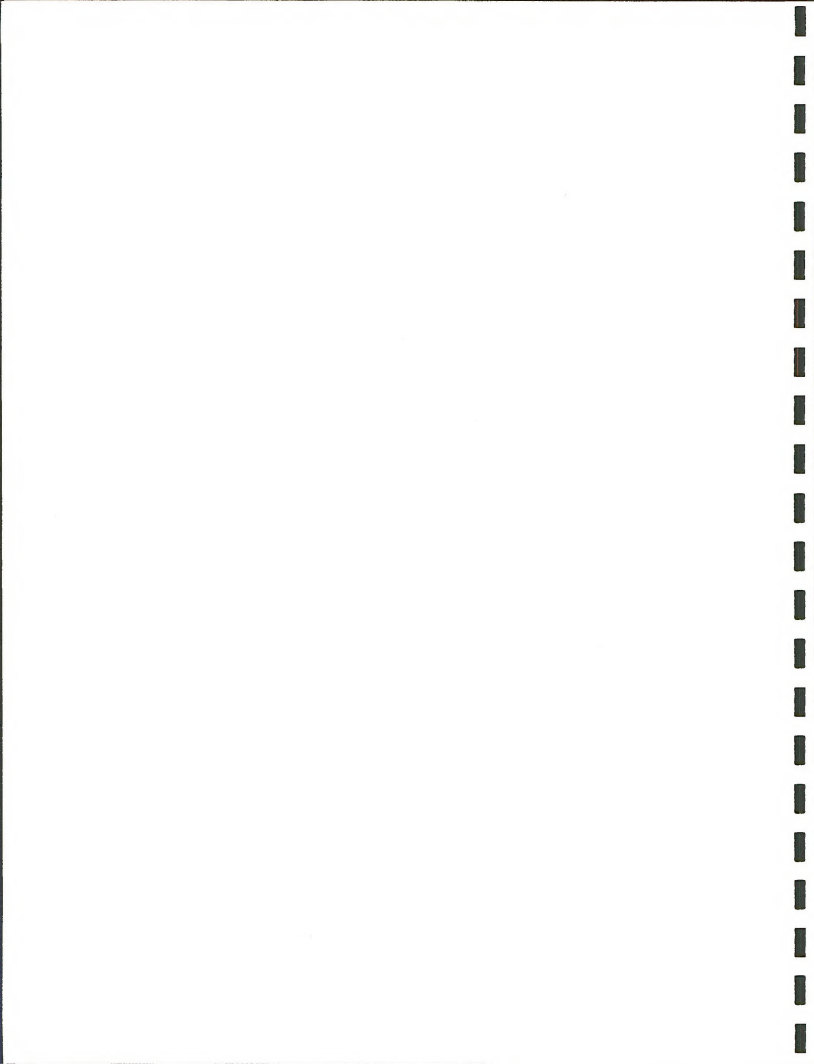
Purpose and Scope

This thesis investigates the spatial distribution of trace elements in surficial materials in the vicinity of oil shale lease tract C-a in the Piceance Basin of northwestern Colorado (Figure 1). The primary objectives of this study are: 1) to determine the average values and ranges of trace elements in the various media, and 2) to determine the sources of the natural variations in the geochemical environment. Other goals of the survey are to evaluate the applicability of the grid sampling design and develop geochemical maps for those components which display statistically valid variations.
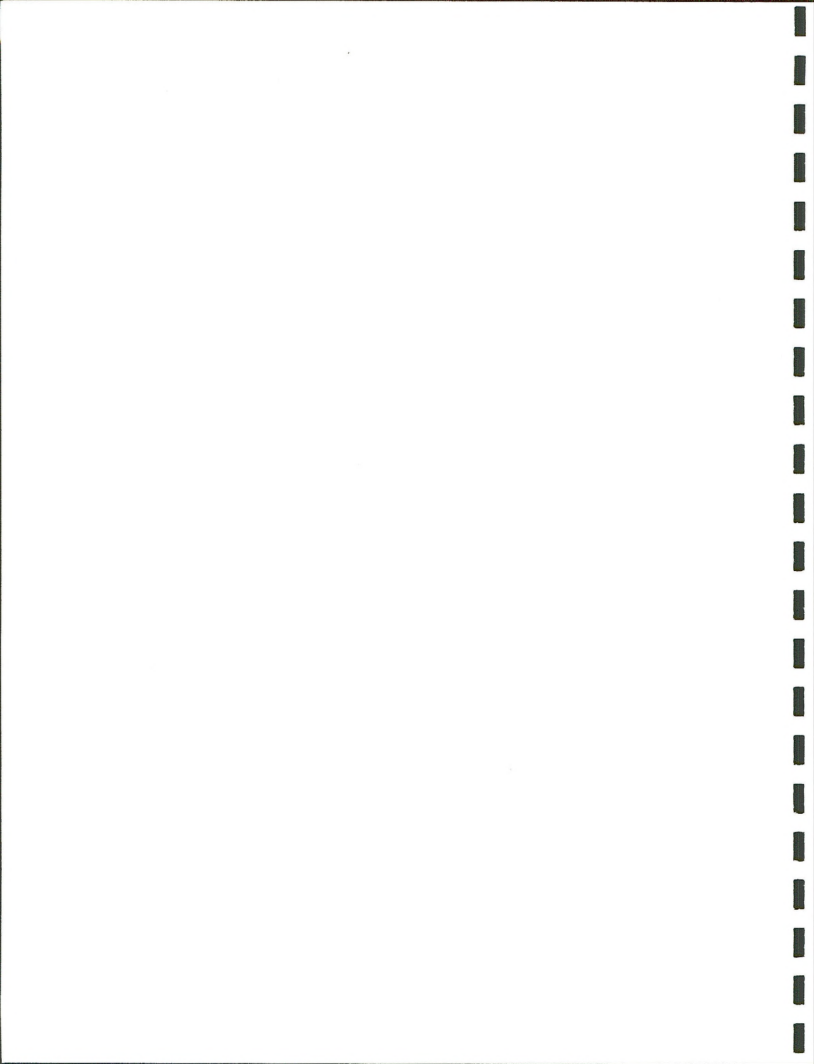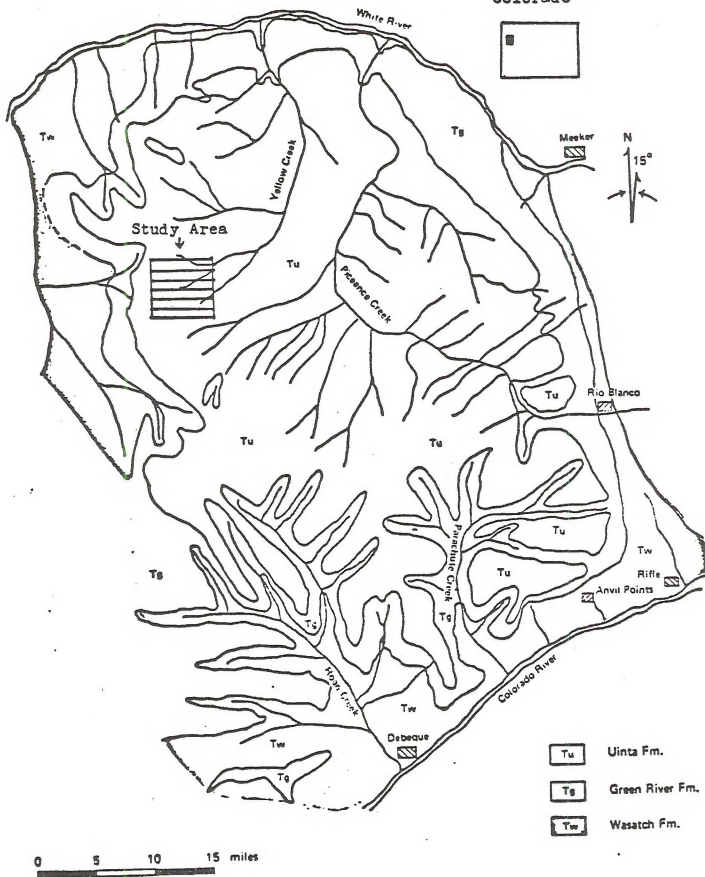
Figure 1. Simplified geological map of the Piceance Basin (Ringrose,1976)
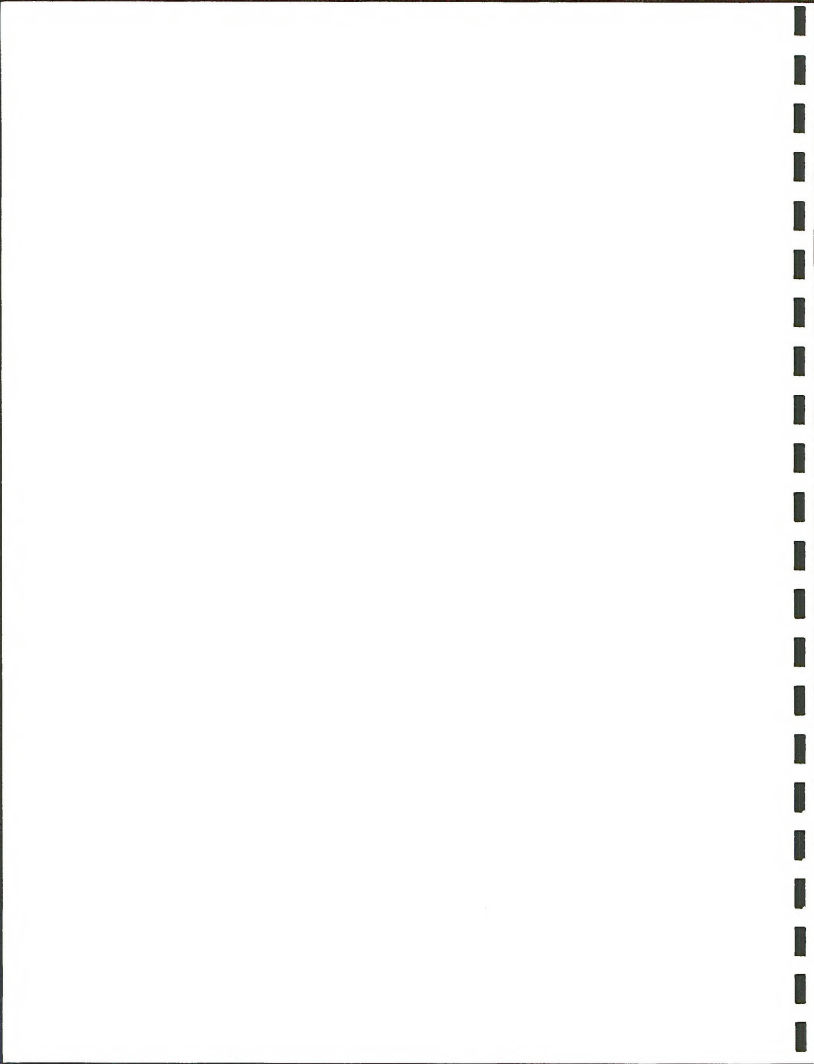
GEOLOGIC AND GEOCHEMICAL SETTING

The Piceance Basin is a large northwest trending structural downwarp bounded on the north by the White River, on the east by the White River Uplift and the Grand Hogback, on the south by the West Elk Mountains and Uncompahgre Plateau, and on the west by the Douglas Creek Arch.

The Piceance Basin was an area of deposition during the Eocene epoch. This fact is shown by the thickening of sediments towards the axis of the basin and thinning towards the margins of the basin. The time of formation of the basin was probably during early Eocene time because of the presence of basal Wasatch sediments thickening towards the center of the basin (Donnell, 1961). At the end of the Cretaceous and during Tertiary time, the Laramide and the post Laramide orogeny formed the basis for the structural features seen in the Piceance Basin today. After the deposition of the extensive oil shales of the Green River Formation, many basalt flows were extruded on the broad flat area of the Piceance Basin. Eocene and post Eocene structural deformation were the most intensive episodes of folding affecting the region. Further uplift in middle Pliocene time caused the 5000 feet of downcutting expressed by steep cliffs in the area today. More gentle uplift continued throughout the Quaternary period creating the more subdued landscape in the central portion of the basin (Murray and Haun, 1974).

The most important stratigraphic units are shown in Figure 3. The Wasatch Formation is a varicolored claystone and shale displaying shades of gray, red, purple, and green. It also has sections of massive to crossbedded, mostly lenticular sandstone. The age is considered to be at or near the Paleocene-Eocene boundary.

The Green River Formation overlies the Wasatch Formation and contains the richest deposits of oil shale. The Green River Formation is divided into three members. The Douglas Creek, Garden Gulch, and Parachute Creek members consist of massive to platy dolomitic marlstone. The Mahogany zone of rich oil shale is contained in the Parachute Creek member and can be traced over large portions of the basin. The Green River Formation is considered to be middle Eocene in age (Hail, 1974).

The sandy Uinta Formation overlies the Parachute Creek member of the Green River Formation and is the dominant unit in the tract C-a area. The Uinta Formation was renamed from the Evacuation Creek member (Cashion, 1974) and consists primarily of brown sands but also contains lenses of material that resembles portions of the Parachute Creek member.

The lacustrine sediments in the Piceance Basin were deposited in varying stages. As Lake Uinta became more alkaline, stratification of the water developed. As this chemical stratification continued the pH of the lower level

EXPLANATION FOR CROSS-SECTIONS

RED BED FLUVIATILE—Red mudstone and sandstone

NON-RED BED FLUVIATILE—Grey and green mudstone and sandstone

PALUDAL—Grey carbonaceous shale and sandstone

FRESHWATER POND—Grey molluscan limestone and interbedded grey shale and sandstone

TUFFACEOUS FRESHWATER LACUSTRINE—Grey and tan tuffaceous sandstone, siltstone, shale and some brown oil shale

FRESHWATER LACUSTRINE—Brown low grade (poorly) oil shale, abundant ostracodes, sexton and mollusks

SALINE LACUSTRINE—Dark brown to black dolomitic oil shale, fish fossils

EVAPORITE—Nahcolite, halite, dawsonite, ore, and brown to black oil shale

MUD FLAT—Green and grey dolomitic mudstones, some oil shale, abundant algal mats, desiccation structures

Unconformity

Sandstone

Mollusca-bearing sandstone or limestone

Algal (reef) limestone

Figure 2. Plan Map Showing Location of Core Holes Used in the Stratigraphic Cross Section. (Rohler, 1974)
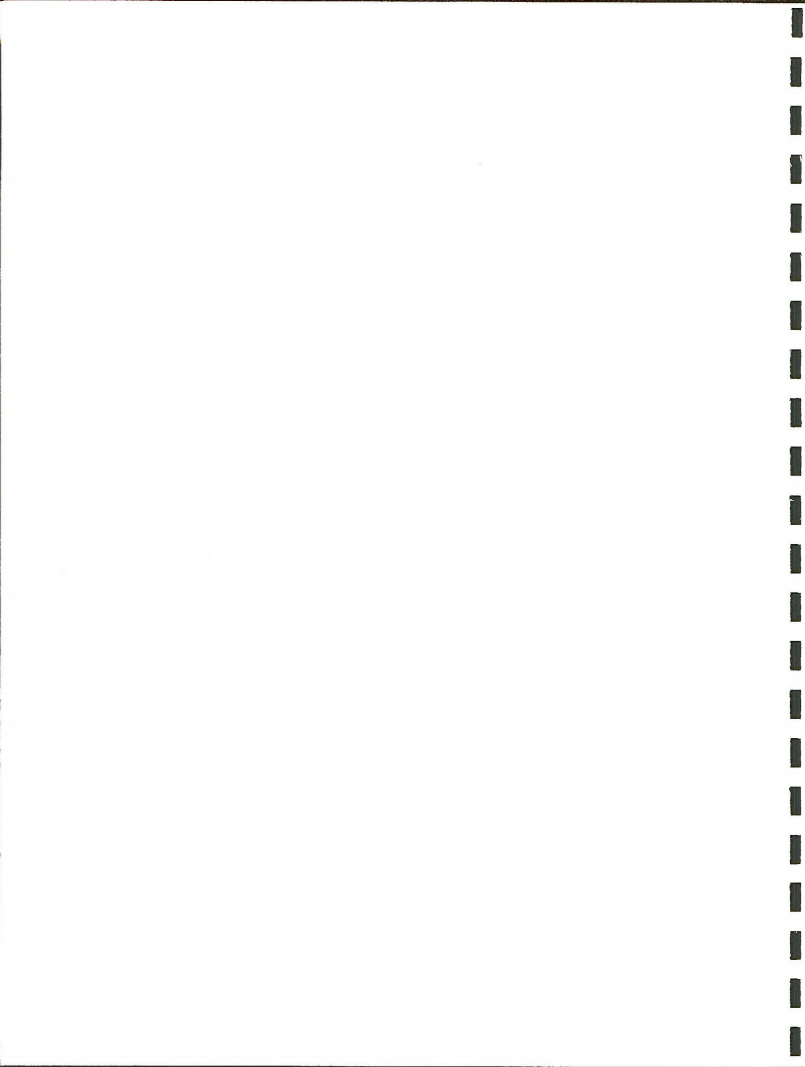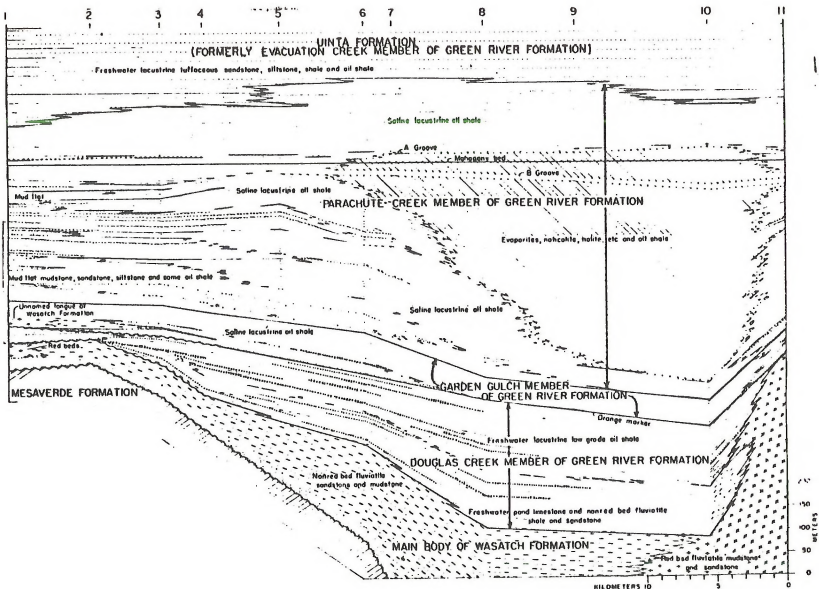
Figure 3. Cross Section of Lithology in the
Central Portion of the Piceance Basin. (Rohler,1974)
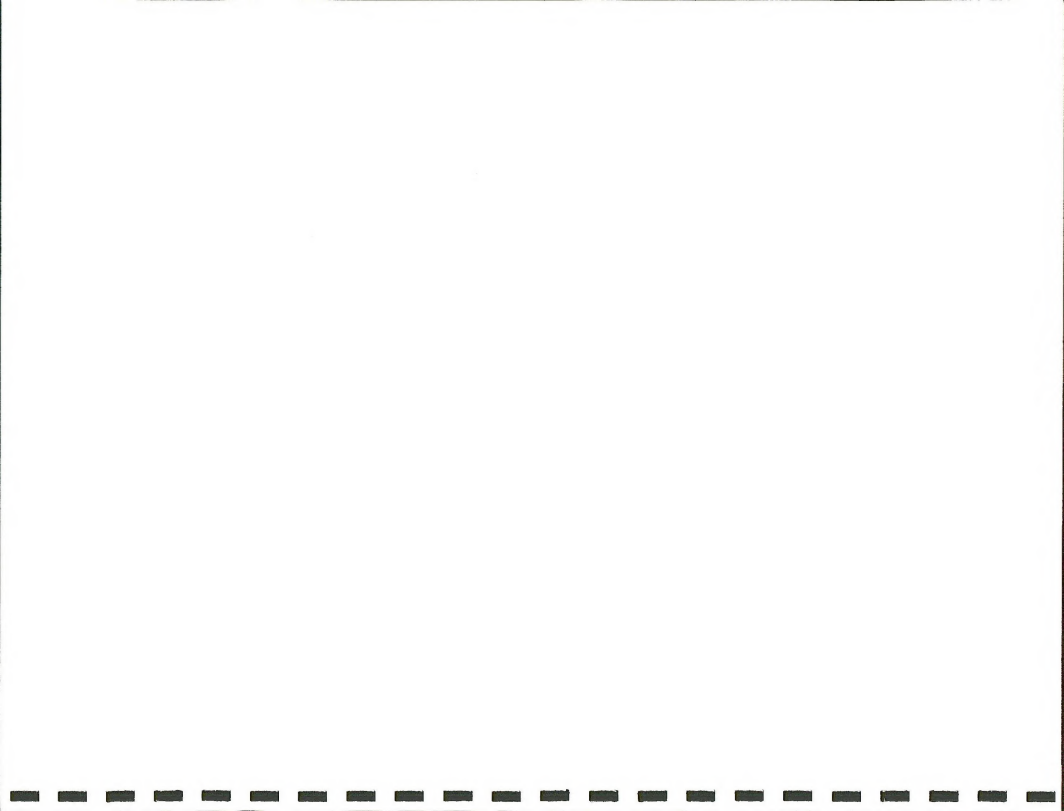
waters rose until the lake's lower area was a solution of
sodium bicarbonate. Organic material was deposited and
preserved along with evaporite minerals such as halite and
nahcolite until clastic deposition resumed and the Uinta
sediments filled the basin (Smith, 1974).

A basic understanding of these processes allows pre-
dictions to be made about the materials of environmental
concern. The black shales in the Green River Formation were
deposited in unusually high pH conditions whereas most
organic shales are deposited in acidic conditions. This
explains the fact that elements such as Mo, B, Se, and F
are elevated in concentration. These elements generally
become more mobile in alkaline conditions and are toxic to
plants or animals, thus they are of prime environmental
concern.

Previous work in the Piceance Basin (Ringrose and
Klusman, 1976b), indicates that these elements are indeed
elevated in concentration and may pose pollution hazards
during oil shale development. Table 1 shows some values of
trace elements in rocks and soils from the earlier studies
and compares them with crustal averages. The whole rock
analyses were determined by x-ray fluorescence. Many of the
elements vary greatly over localized areas making inter-
pretations difficult but Zn, Cu, Li, Fe, and Be displayed
significant regional trends with highest concentrations
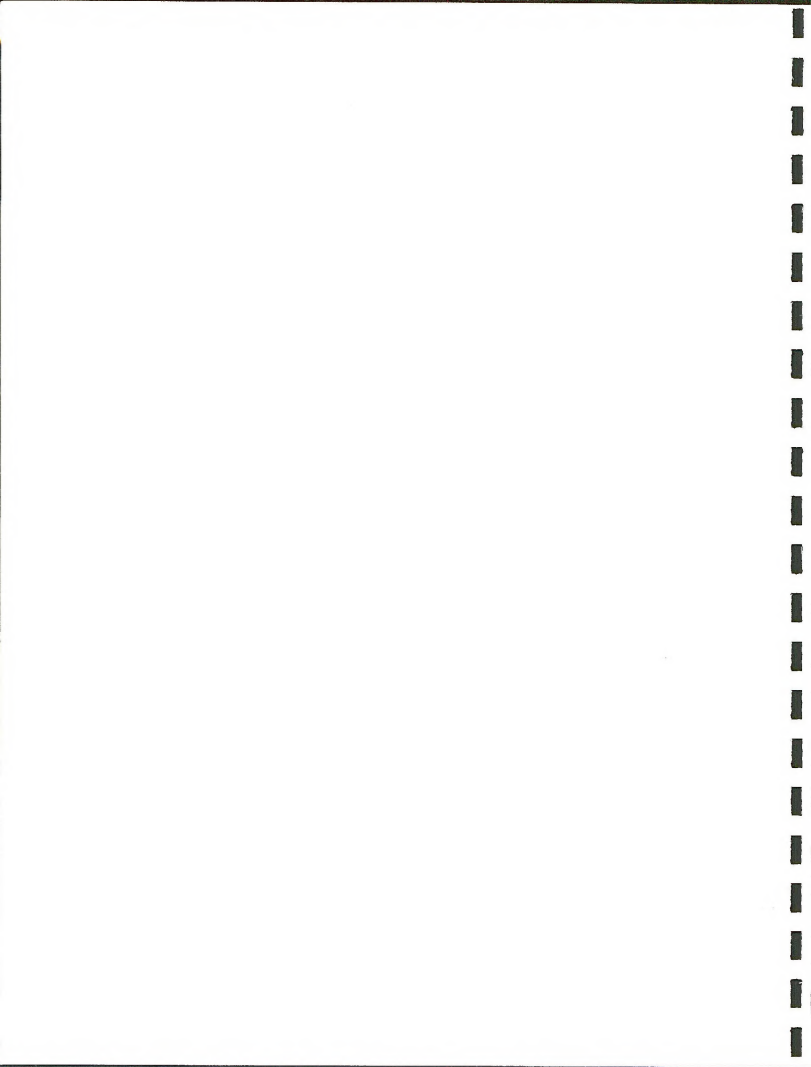
Table 1. Trace Elements in Rocks and Soils of the Piceance Basin versus Crustal Averages.

Element	Crustal[1] Avg.	Shale[1] Avg.	Uinta[2] Formation			Parachute[2] Creek Formation			Piceance[3] Basin Soils
			Min.	Avg.	Max.	Min.	Avg.	Max.	
Mo	1.5	2	2	3	6	3	17	40	5.3
As	1.8	6.6	5	10	21	9	33	110	6.4
Se	0.05	0.60	2	2	3	2	2	2	0.28
Zn	70	80	19	39	52	29	47	95	80
Hg	0.08	0.4							0.041
Li	20	60							34
B	10	100							61
Cd	0.2	0.3							-

[1] Krauskopf, 1967

[2] Whole Rock Analysis by X-ray Fluoresence Klusman and Ringrose, 1977

[3] Ringrose et al, 1976b
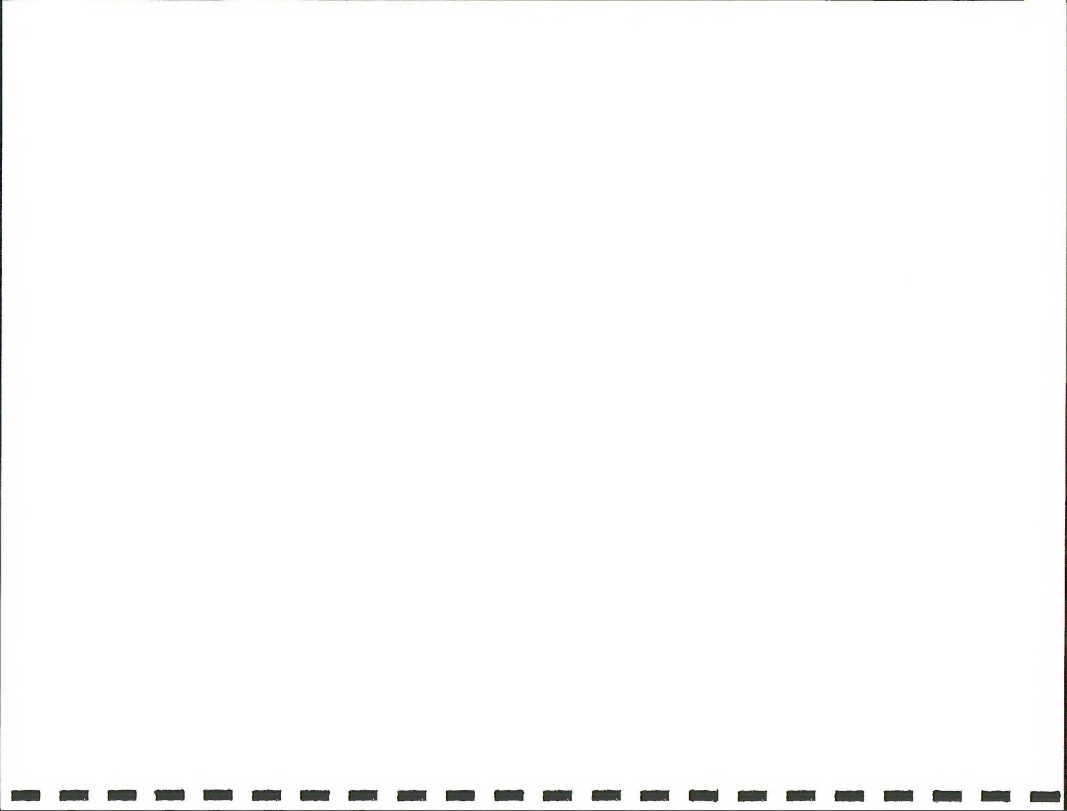
observed in the southern part of the basin (Ringrose et al, 1976b).

Both the Parachute Creek member and Uinta Formation outcrop in the vicinity of tract C-a so a reconnaissance geologic map (Figure 4) of the study area was prepared by the author to separate the sample localities according to the geologic unit from which they were derived. The definition of these two populations is difficult because of the interfingering of tongues of Parachute Creek member in the Uinta Formation. Therefore the distinction rests upon the variation in color of the soils. In all cases the Parachute Creek soils are white-gray in color and in most instances the Uinta Formation soils are brown.

N

15°

Parachute Creek
member of the
Green River Form.

Tu

Uinta Formation

0   ½   1

Miles

Figure 4. Geologic Map of the Study Area.
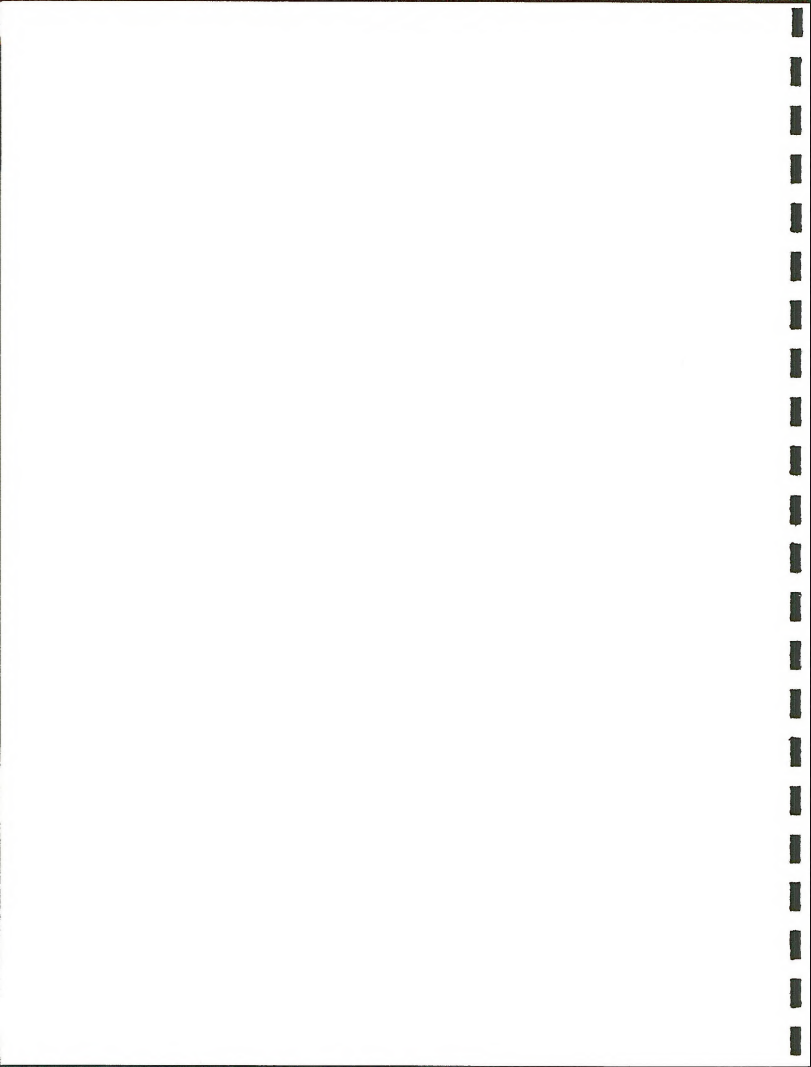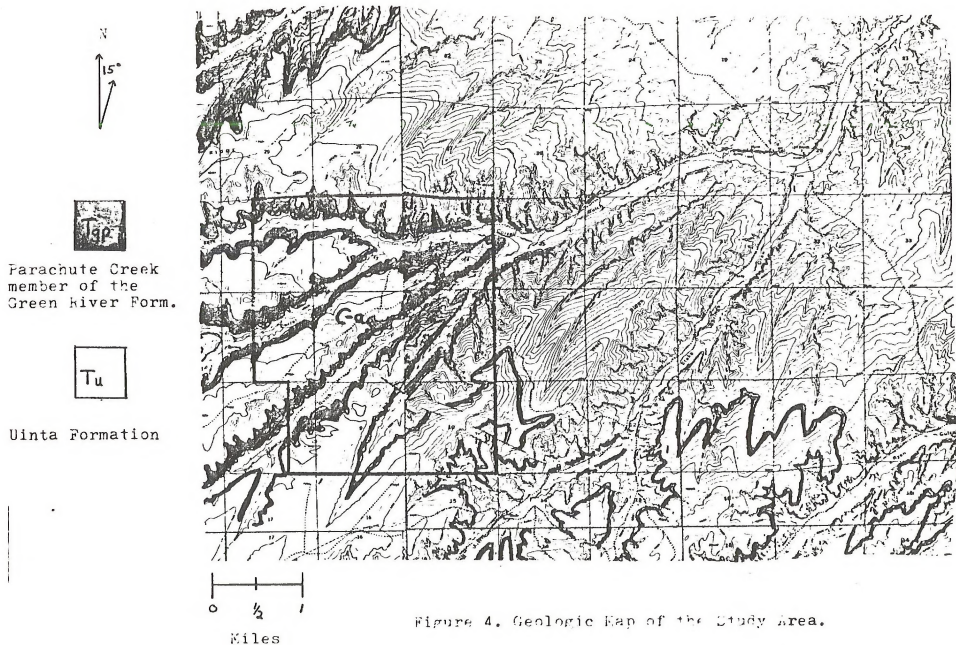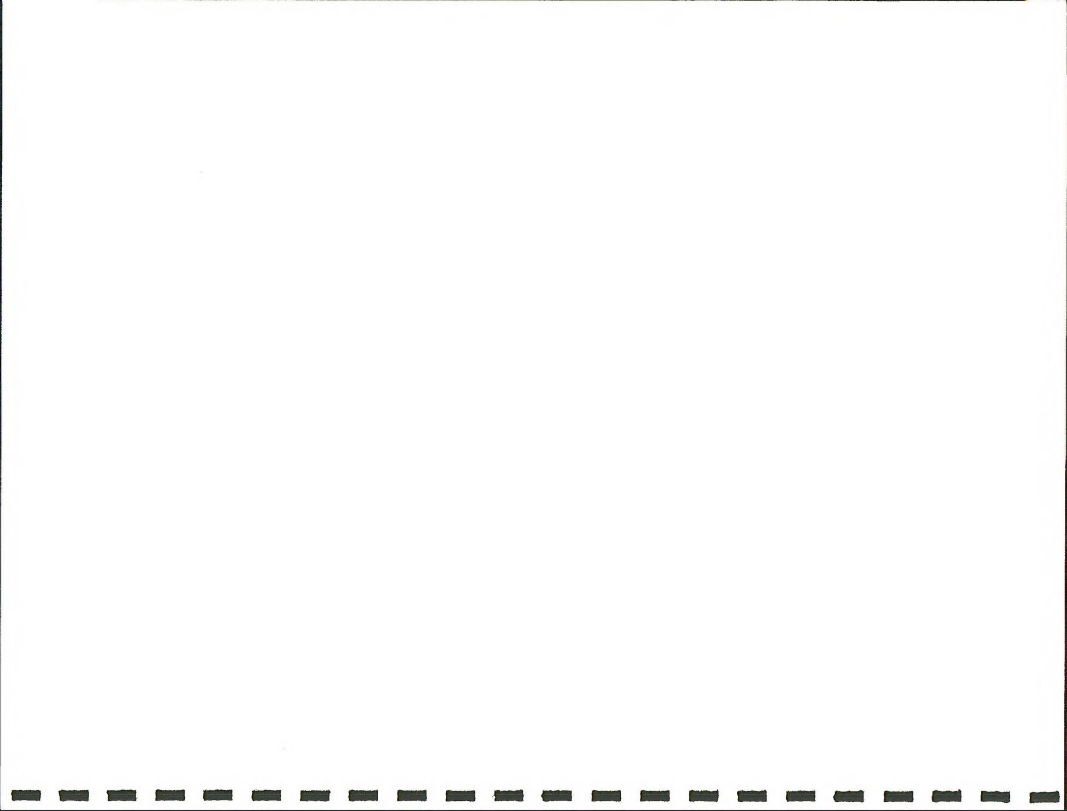
SAMPLE DESIGN AND COLLECTION

The sampled area is eight by six miles incorporating tract C-a and downwind areas. Sample localities were placed at half mile intervals in a grid pattern within the area (Figure 5).

In addition, thirty-two analysis of variance samples were selected from four randomly chosen sections (Figure 6). Subsampling in each of the four sections is also randomized. The grid spacing was determined as a result of previous studies (Ringrose, Klusman, 1976b) in which a significant amount of the unexplained variance of trace elements was contained at this scale.

At each location soil and three plant species were compositly sampled over an area of fifty to one hundred square meters depending on plant availability. Composite sampling was done to reduce the localized (0-10m) variance evident from previous studies. Plants collected include big sage (Artemisia tridentata-tridentata and subspecies Artemisia tridentata-wyomingensis), Indian rice grass (Oryzopsis hymenoides), and Western wheat grass (Agropyron smithii). The choice of these particular plants was based on suggestions from range specialists at Colorado State University, Area Oil Shale Supervisors Office and Meeker offices of the Bureau of Land Management and Soil Conservation
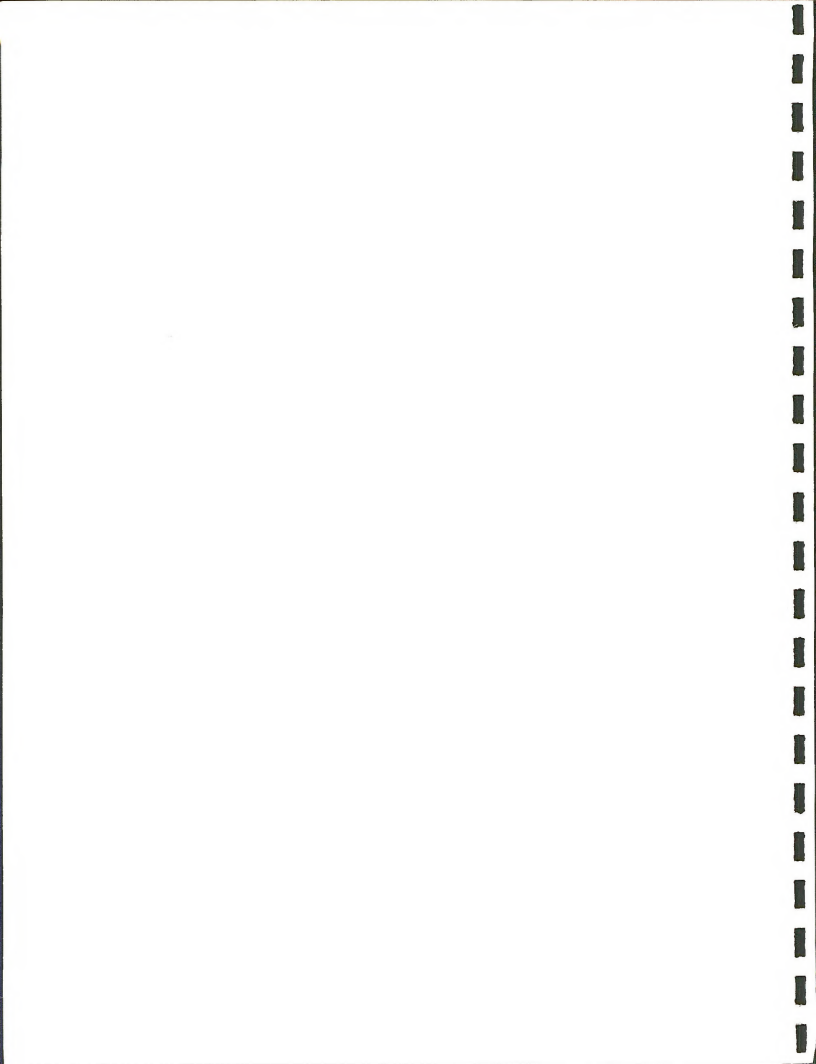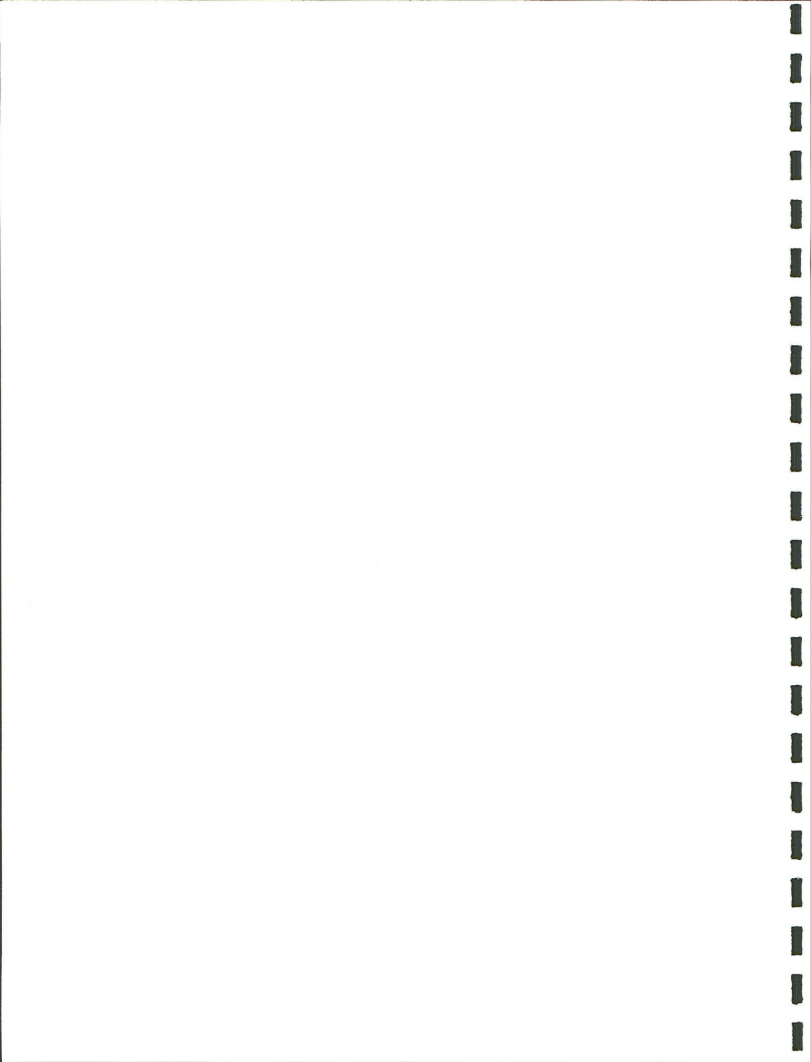
Figure 5. Plot of Grid Sample Locations.
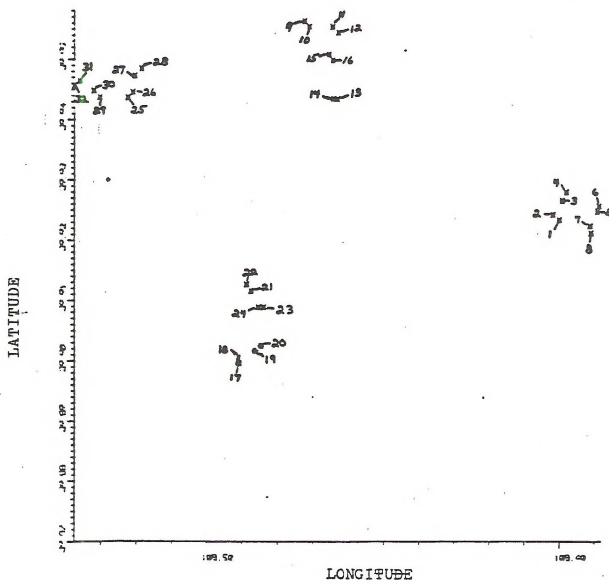
Figure 6.   Plot of Analysis of Variance
Sample Locations.
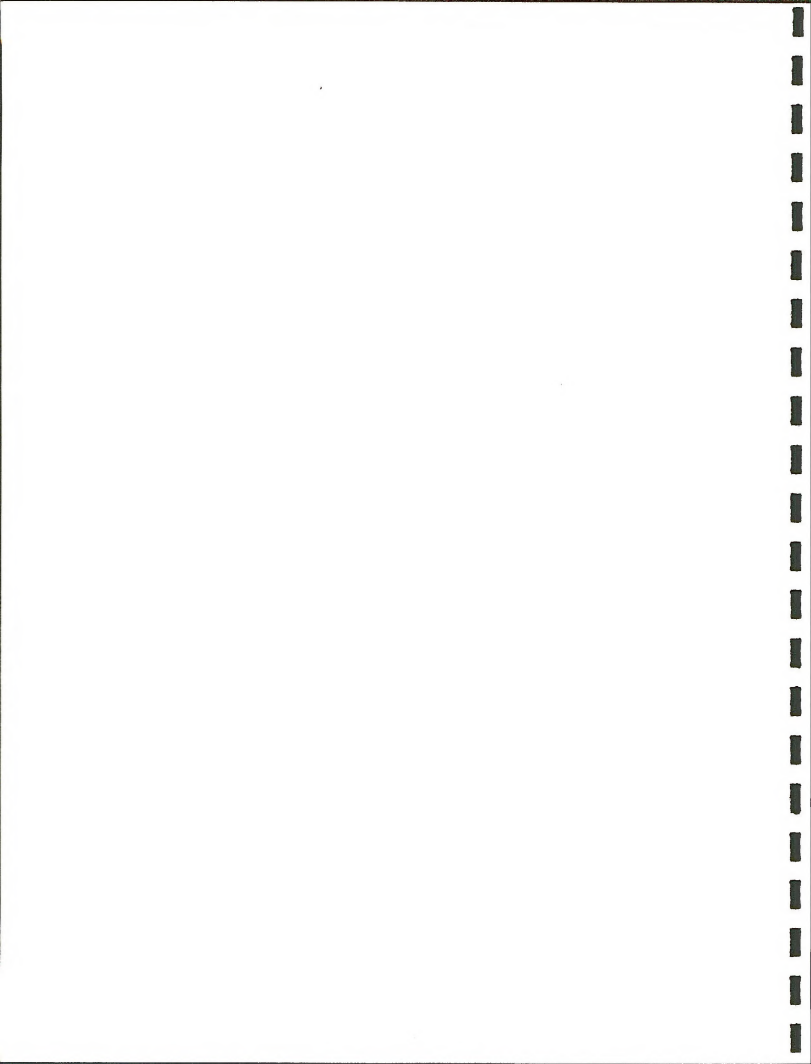
Service because of their availability and importance as forage by cattle and native herbivores, and potential for use in revegetation of spent shale dumps.

The soil samples are from the A horizon and were sieved in the field with a 4 mesh stainless steel sieve into a plastic beaker. The soils were transported in paper bags as was the plant material.

Stream sediments were also collected in most of the streams and gulches up and downstream from the grid area as well as within the area. Stream sediments were composited over at least 10m and collected at one-half mile intervals.

All the samples were collected in July and August, 1976.
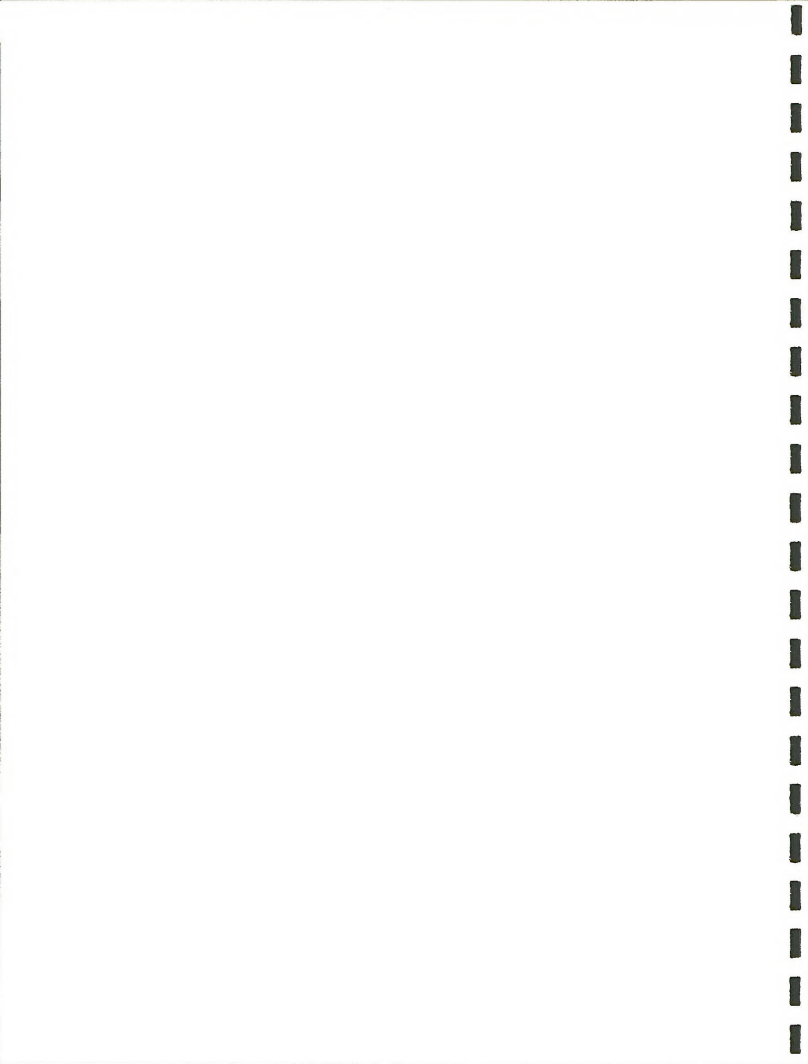
CHEMICAL ANALYSIS

Analytical determinations were performed by the Project
Central Analytical Facility at the University of Colorado
and also at Colorado School of Mines. The elements B, As,
Mo, F, and Se cannot be easily analyzed at present at the
Chemistry-Geochemistry Department of Colorado School of
Mines. Project Central Analytical Facility has completed
analysis only of B and Mo in the soils and plants because
of soil matrix interferences that hinder the analysis for the
other elements. At C.S.M., Cd, Zn, Hg, and Li were analyzed
in soils as elements of secondary environmental and geo-
chemical interest. The Cd analyses were abandoned because
of the strong suspicion of chemical interference from Ca.
The Ca causes higher values of Cd to be observed. There is
a strong association between Zn and Cd in most geochemical
environments. The Zn values are near crustal average so it
is expected that the Cd should also be near crustal average.
The Cd values are high and positive correlations exist
between Cd and Ca. Since Ca is common in the marlstones in
the study area the Cd results found were probably erroneous.

All the elements were determined by direct atomic
absorption methods except for Hg which used a flameless
atomic absorption method and Mo in plants which is done
colorimetrically. The analytical methods and sample prepara-
tions are described in detail in Appendix I.
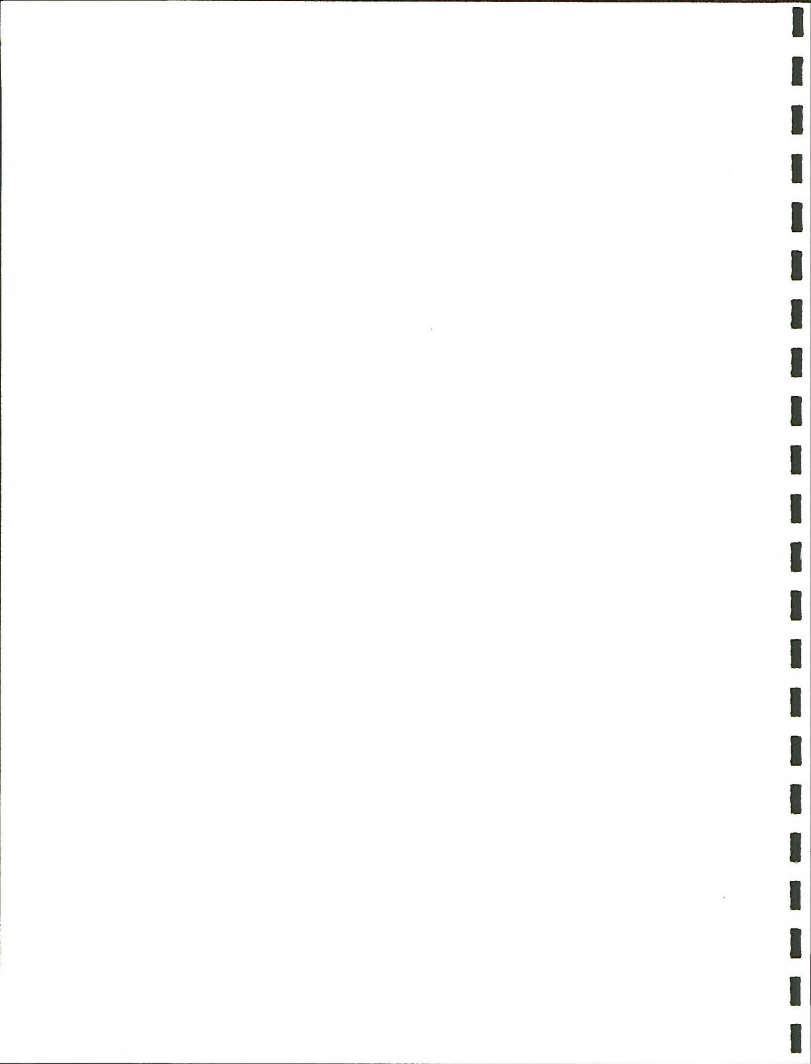
STATISTICAL ANALYSIS

Analysis of Variance Design

The definitions of sample localities and factors are as used in papers by Miesch (1976a, 1976b). The samples were collected as in Figure 7. The sampling was designed to analyze the variability shown in five separate levels (Figure 8). The levels are: variance at the greater than 1.6 km level, variance at the 0.4 km level, variance at the 0.1 km level, variance between samples at the 50 m level, and error in the chemical analysis. The model is defined as:

$$X_{ijklm} = u + a_i + b_{ij} + c_{ijk} + d_{ijkl} + e_{ijklm}$$

where u is the mean of all the nested samples, a is the regional component (>1.6 km), b is the 0.4 km segment, c is the 0.1 km segment, d is the 50 m segment, and e is the analysis. The population variance is divided as follows:

$$\sigma_x^2 = \sigma_a^2 + \sigma_b^2 + \sigma_c^2 + \sigma_d^2 + \sigma_e^2$$

and is calculated as the sample variance:

$$S_x^2 = S_a^2 + S_b^2 + S_c^2 + S_d^2 + S_e^2$$

The complete analysis of variance data are listed in Tables 11-14 in Appendix II. In Table 2 the geometric means and deviations and variance ratios are listed. The methods used to calculate the geometric means and deviations are given in Appendix II. In the interpretation of the analysis

one mile
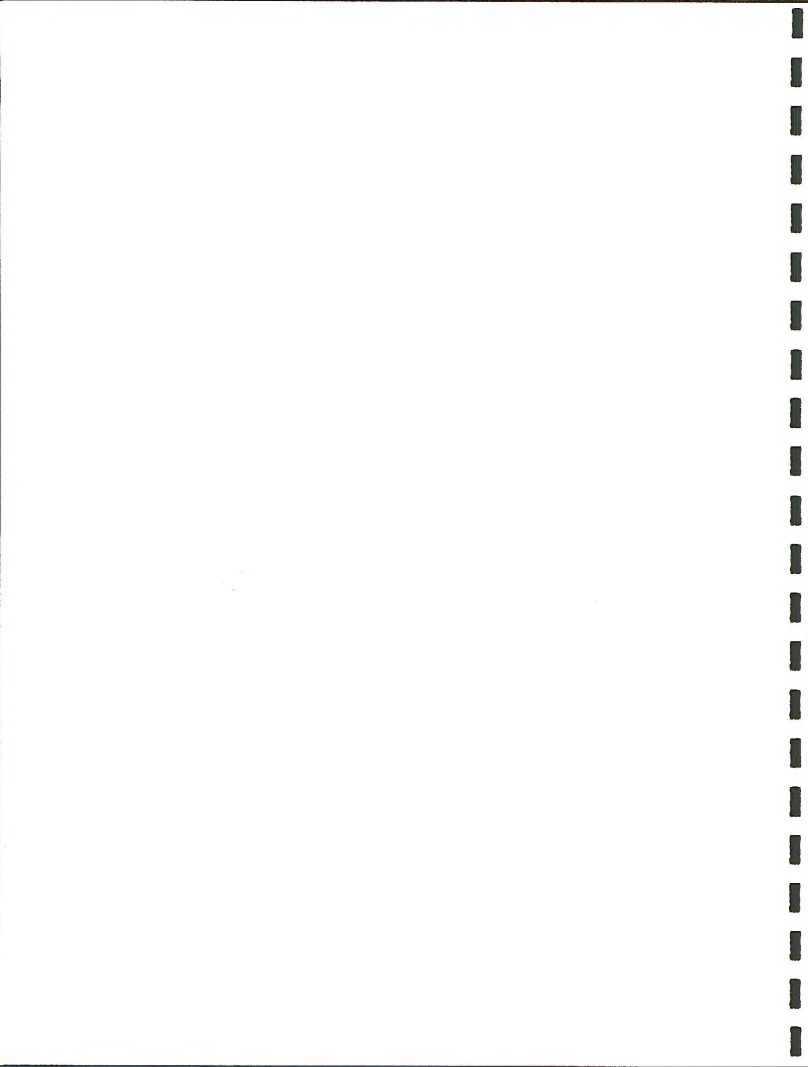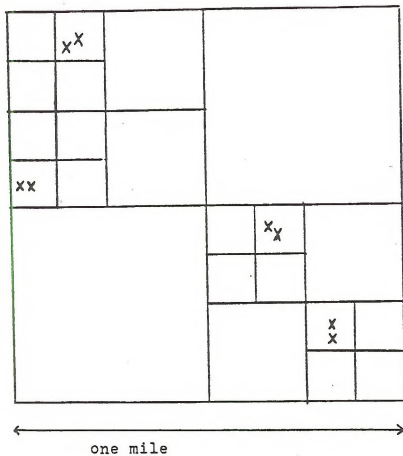
Figure 7. Schematic of Analysis
of Variance Sampling Design

> 1.6km

0.4km - 1.6km

50m - 0.4km

0 m - 50m

analytical
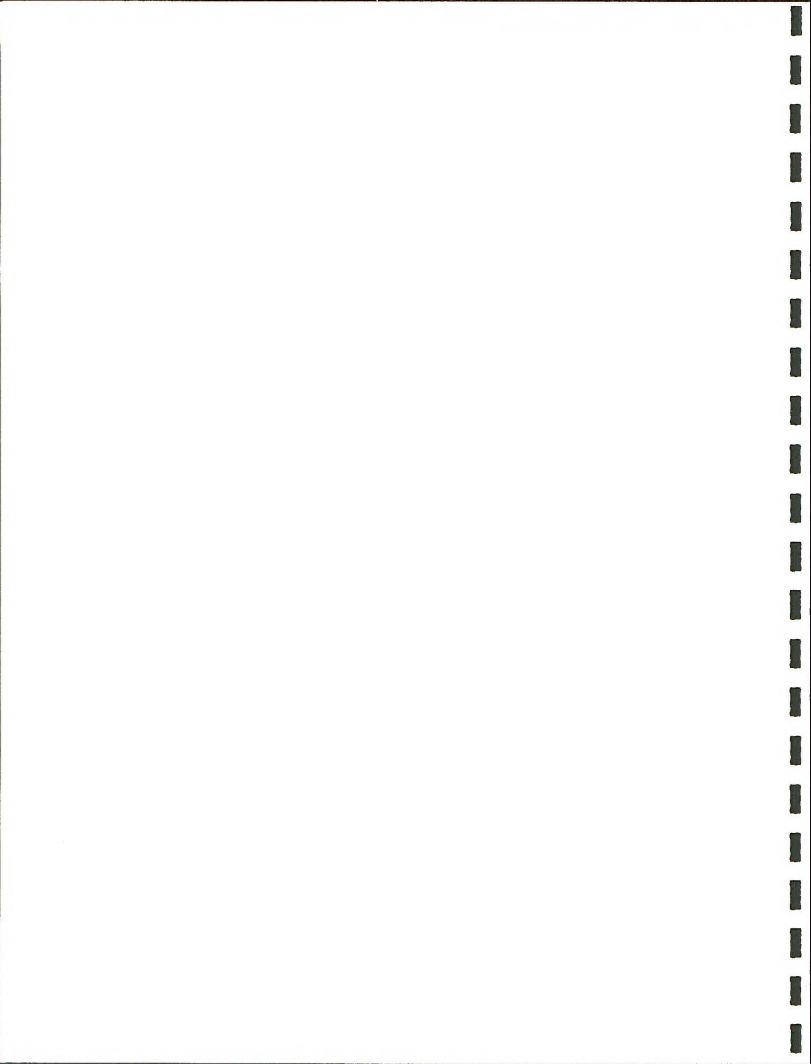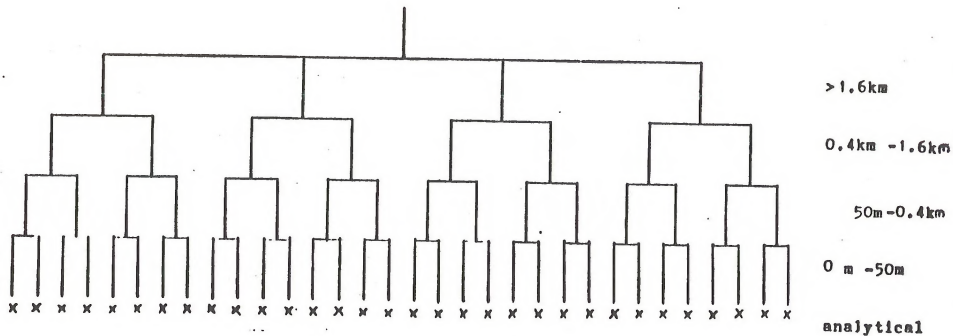
Figure 8. Nested Model of ANOVA
Samples. Levels are described at
the right of the model.
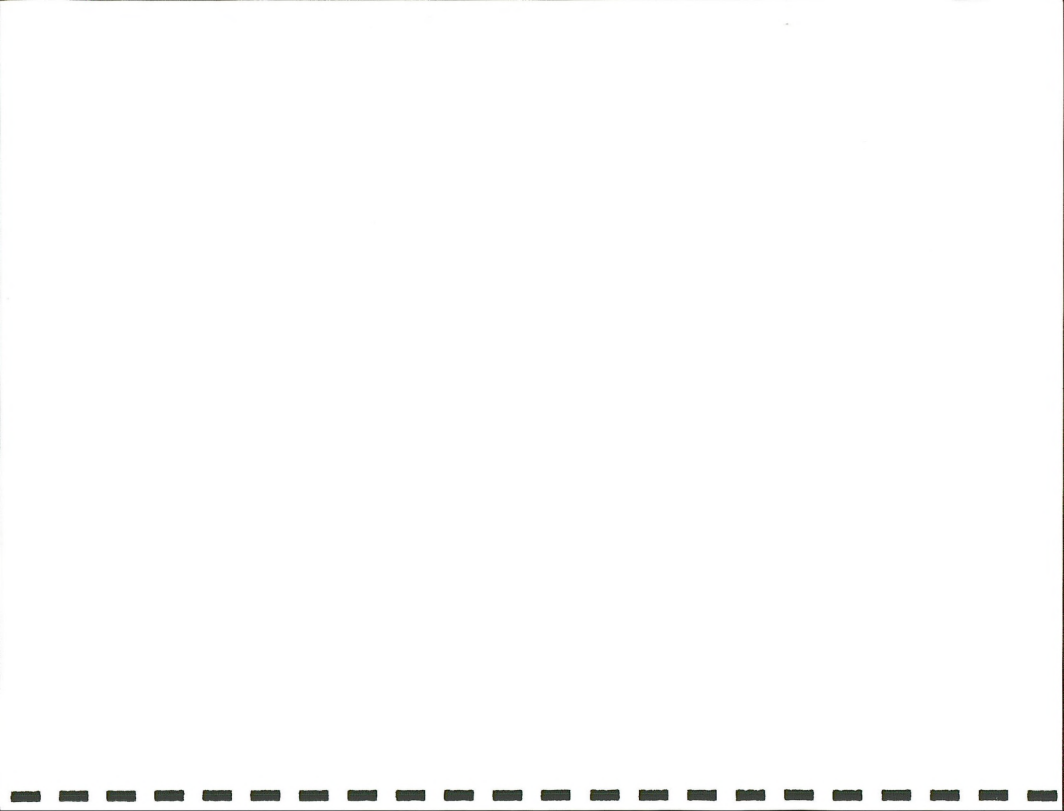
of variance design, ratios of the variances at different
levels of the sampling model are examined. The variance
ratio (V) is the ratio of the variance between sections
(>1.6 km) and the sum of the variance at the other levels
of the model (0.4 km, 0.1 km, 50 m, and analytical error).
The larger the variance ratio the greater the probability
that the component in question displays a regional compon-
ent of variation. The variance mean ratio (V_m) is similar
to the variance ratio but incorporates the nested design of
the sampling model used (see Appendix II). The maximum
acceptable error variance for a balanced sampling design
(E_r) and the error variance for a hierarchial design (E_s)
are used to determine the stability of a geochemical map
(Miesch, 1976a). If the variance observed in a nested
design (E_s) is less than the maximum permissible error var-
iance for a balanced design (E_r), then the model produces
an accurate representation of the variance shown by the
particular component (Miesch, 1976b). This also supports
the stabilities of the estimates of the means and suggests
there is a significant regional component of variance
(>1.6 km) for As, Li, Mo, and organic carbon in soil and B
and Mo in sage. If the variance ratio is zero it implies
there is no regional component of variance and the maps for
these components are not stable. This is the case for Hg,
B, and pH in soil and Hg, Zn, B, and Mo in wheat grass and
also Zn in rice grass (Table 2).
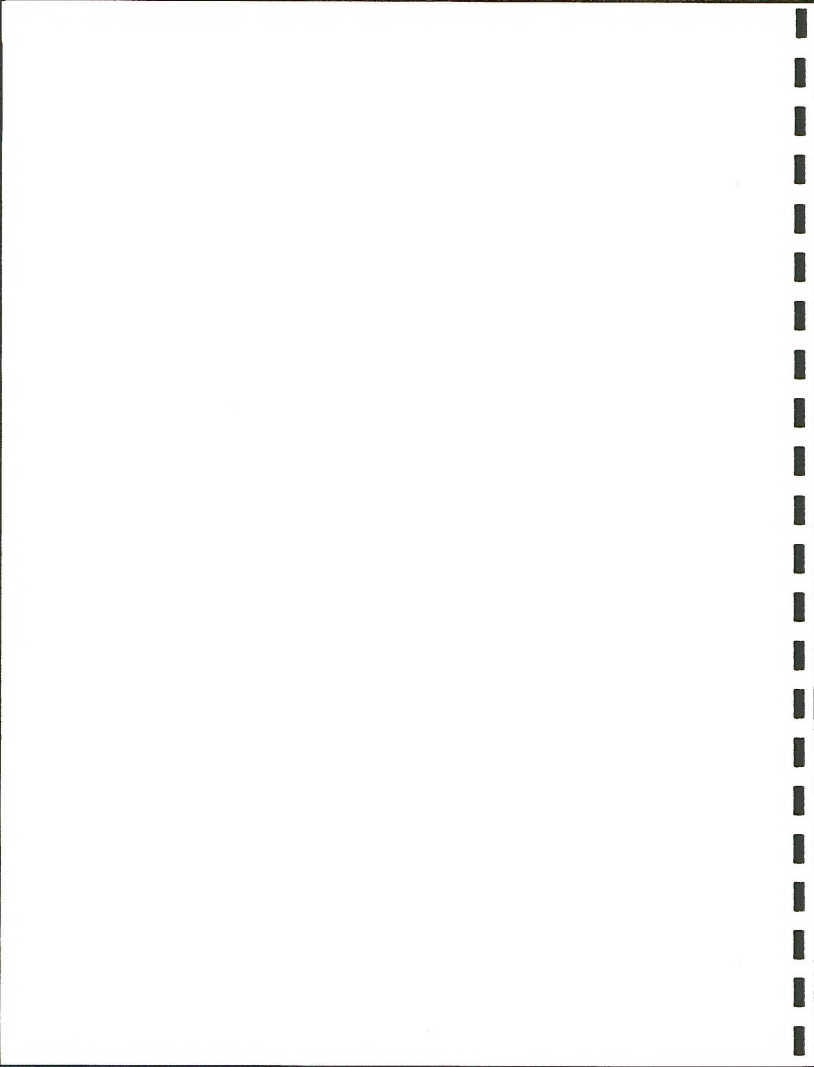
Table 2. Geometric Means and Deviations and
Variance Ratio Results for Tract C-a Data.

ELEMENT AND MEDIA	95% RANGE	GEOMETRIC MEAN	GEOMETRIC DEVIATION	VARIANCE[**] RATIO	VARIANCE MEAN RATIO	N_r	E_r	E_s	# of SAMPLES
WHEATGRASS									
Hg(ppb)	7.5–70	23	1.75	–	–	–	–	–	25
Zn(ppm)	5.1–18	9.6	1.38	–	–	–	–	–	25
B(ppm)	7.7–28	15	1.38	–	–	–	–	–	25
Mo(ppm)	0.54–2.4	1.2	1.45	–	–	–	–	–	25
RICEGRASS									
Hg(ppb)	11–52	24	1.47	0.05	2.97	60	0.00059	0.00061	32
Zn(ppm)	0.49–18	2.6	2.46	–	–	–	–	–	32
B(ppm)	3–32	10	1.81	0.02	2.96	45	0.0004	0.0001	32
Mo(ppm)	0.48–2.3	1.1	1.48	0.24	3.95	4	0.0068	0.0017	32

[*]
Arithmetic mean and deviation for pH (pH is a log measurement)

[**]
If the estimated variance between sections is zero V_m, N_r, E_r, E_s are not
calculated.
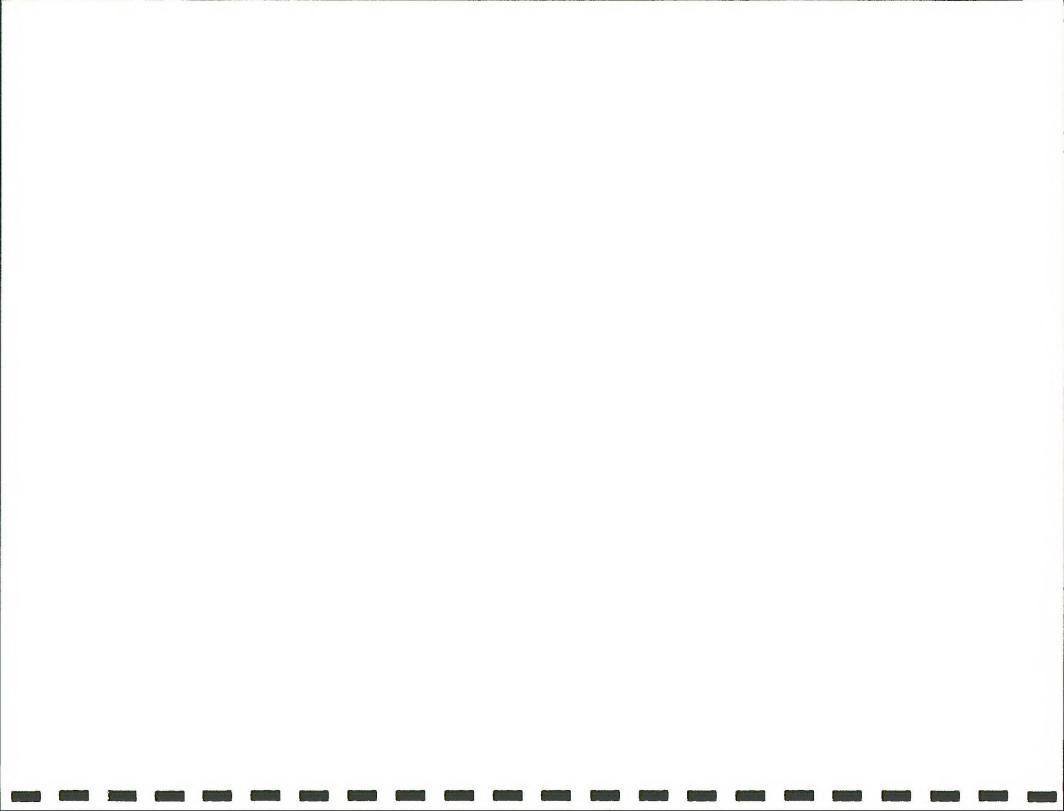
Table 2. Continued.

ELEMENT AND MEDIA	95% RANGE	GEOMETRIC MEAN	GEOMETRIC DEVIATION	VARIANCE RATIO	**VARIANCE MEAN RATIO	N_r	E_r	E_s	# OF SAMPLES
SOILS									
Hg(ppb)	30-58	42	1.18	.-	.-	-	-	-	253
Zn(ppm)	39-123	70	1.33	0.02	4.17	45	0.019	0.0002	253
Li(ppm)	9-40	20	1.43	0.41	4.32	3	0.011	0.003	253
B(ppm)	78-195	123	1.26	-	-	-	-	-	253
Mo(ppm)	0.46-4.7	1.6	1.70	0.23	4.28	4	0.011	0.003	253
As(ppm)	4-18	8.7	1.43	1.36	4.40	2	0.0071	0.0048	32
Organic Carbon %	0.46-2.9	1.2	1.58	1.03	3.96	3	0.013	0.010	253
pH	7.1-8.5	7.8*	0.353*	-	-	-	-	-	253
SAGE									
Zn(ppm)	0.43-11.	2.2	2.26	0.02	2.96	45	0.004	0.001	32
B(ppm)	21.5-42.6	30.3	1.19	0.46	3.74	2	0.0024	0.0006	249
Mo(ppm)	0.25-1.7	0.65	1.63	0.22	3.90	5	0.0089	0.0026	243
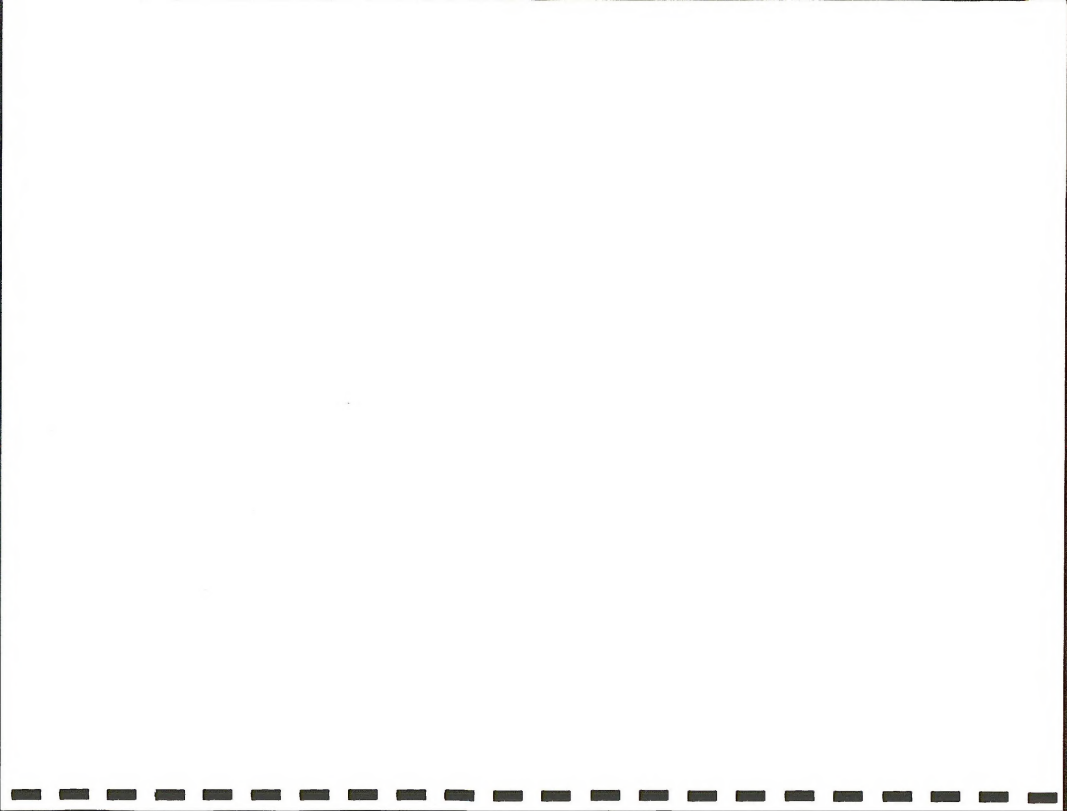
The lack of stability for Hg and Zn in the soils and
plants is probably due to a high component of variance
caused by error in the methods of chemical analysis. Many
of the elements analyzed in wheat grass show little stabil-
ity because the power of the model is reduced. At many of
the analysis of variance sample sites (also many of the
grid localities) wheat grass was not available for collec-
tion, thus the model is less likely to produce non-zero
estimates of variance at the highest level of the model.

All parameters that have non-zero regional variance
components show enough variation for geochemical maps to be
drawn. In most cases those elements with zero regional
components have a high analytical error component. There-
fore the choice of sampling interval and grid spacing was
sufficient to describe most of the variance in this area.

An important step in statistical analysis is to examine
the distributions. The normal convention with trace element
data is to transform the parts per million by a logarithmic
(base 10) conversion. Figure 9 displays histograms of Mo in
the soil samples, first in ppm, then in $\log_{10}$ ppm. A
logarithmic transformation noticeably improves the distribu-
tion to a more nearly normal distribution. The other ele-
ments studied display similar improvements in their distribu-
tions.
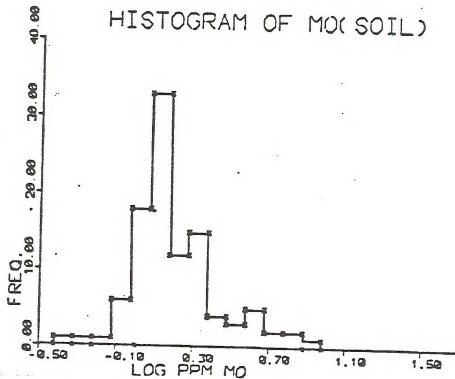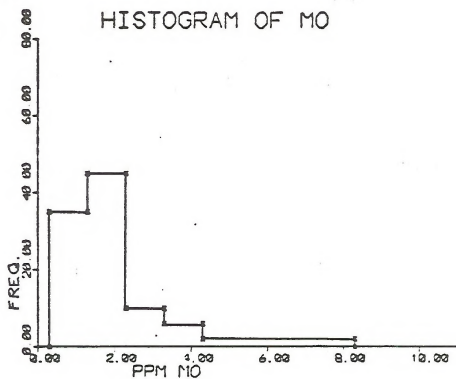
Figure 9. Histograms for Mo in Soil in ppm and Log_{10} ppm.
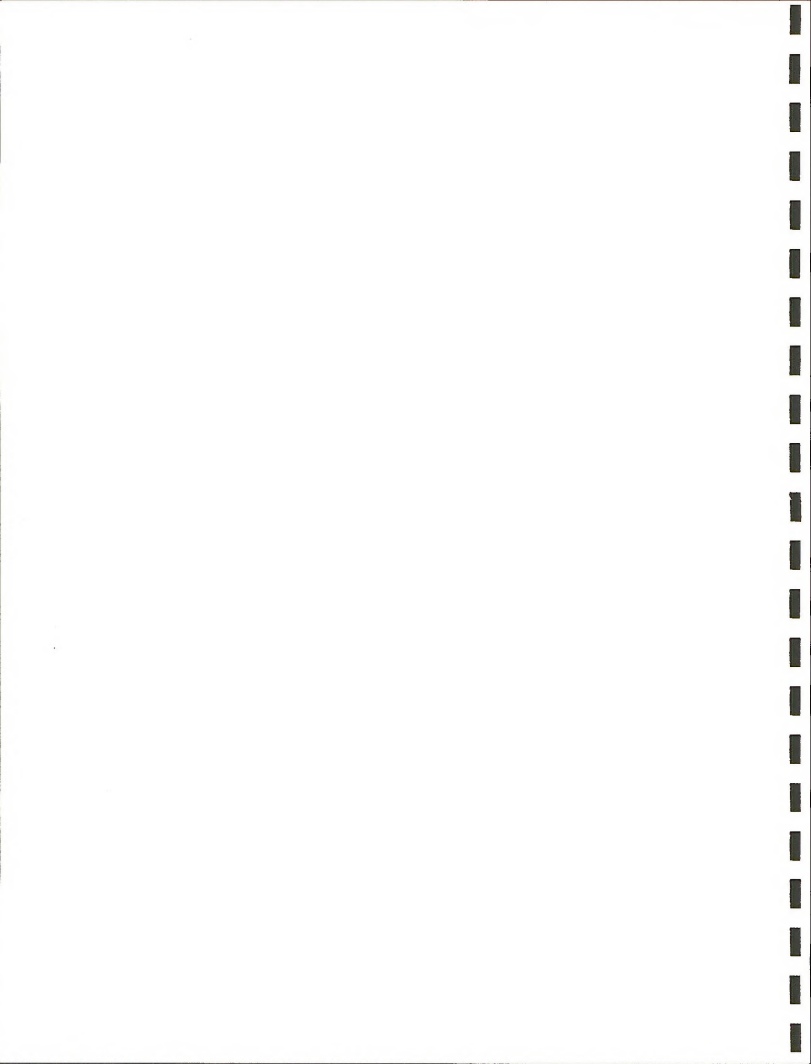
The next step is to compare the means and deviations of
the data. Data collected previously in the Green River Basin
of Wyoming and Piceance Basin is shown in Table 3.

The data in this survey fall within expected ranges for
all of these elements except possibly the B in sage and Zn
in sage. The low mean of Zn (2.2 ppm) in sage is probably
due to analytical errors caused by poor digestions of sage
with perchloric acid (see Appendix I). The B results (30
ppm) are higher than expected and will be discussed later.
No data could be found with rice grass or wheat grass from
similar geographic areas for comparison but the grasses are
elevated in Mo with respect to the sage at the same sample
site. The toxic level in forage for cattle is 5-6 ppm and
the grasses average from 1.1 to 1.2 ppm, so no immediate
problem exists (Gough, 1976).

Table 4 defines the correlation matrix for the compon-
ents analyzed and the correlations are as expected. Organic
carbon and pH are negatively correlated and Mo in soil and
Mo in sage are strongly correlated. Li, Mo, and B also
exhibit a strong positive relationship in the soil samples.
The only inconsistency is the weakly positive relationship
between boron in soils and boron in sage. This is discussed
in the hypothesis testing section.

The samples came from more than one lithology and there-
fore more than one population. This causes problems in the

Table 3. Trace Elements in Soils
of the Piceance Basin and Sagebrush
of the Green River Basin. (ppm)
(U.S. Geological Survey Open File
Report 76-729, Appendix III).

Element	Soils	Sagebrush(dry weight)
Hg	0.041	0.034
Zn	80	28
As	19	0.64
B	61	13
Mo	5.3	0.70
Li	34	1.4
Cd	-	0.34

Table 4. Correlation Matrix
of Tract C-a Vicinity Soil
Samples.

Variable

	Hg	Zn	Li	Org-C	pH	Mo Sage	B Sage	B	Mo
Hg	1.000								
Zn	0.026	1.000							
Li	0.092	0.137	1.000						
Org-C	0.140	0.055	0.395	1.000					
pH	-0.287	0.101	0.077	-0.143	1.000				
Sage Mo	0.130	0.011	0.378	-0.004	0.075	1.000			
Sage B	0.083	0.002	-0.052	-0.114	-0.011	0.037	1.000		
B	0.007	0.048	0.274	0.171	0.089	0.161	0.053	1.000	
Mo	0.119	0.100	0.605	0.143	0.008	0.419	-0.061	0.2156	1.000

interpretation of the analysis of variance data because
the techniques are developed to consider only single popu-
lations. It was suspected that the Parachute Creek member
samples are different from the Uinta Formation samples.
Differences in trace element concentrations are evident
from whole rock analyses (Table 1). This would presumably
affect the regional component of variance in soils because
the Parachute Creek member outcrops only in the western
segment of the study area. The reconnaissance geological
map (Figure 4) allowed the separation of samples according
to lithology. Hypothesis testing can be employed to test
if the differences in means of the samples on the different
formations are significant. Checks on the variances of both
populations revealed no significant differences so the
Student's t test can be used.

Hypothesis Testing

The results of t tests are given in Table 5. Table 5a
shows that all the parameters except Hg and Zn in soils and
the pH of the soils show significant differences between
the Parachute Creek member and Uinta Formation.

Since there is a difference between these two popula-
tions the next logical question is if there are any trends
in either population over the study area. The Parachute
Creek member is so locally distributed that it is probably
safe to assume that there is little change in the concentra-

Table 5a.   Uinta Formation Samples vs Parachute Creek Member
            Samples.

Element	$\overline{X}$ Uinta	s	$\overline{X}$ Par. Crk.	s	t Value	DF
Hg	45.9	1.40	50.1	1.50	1.12	39
Zn	69.2	1.30	73.0	1.35	1.27	42
Li	17.8	1.43	30.2	1.48	6.62**	42
B	121.2	1.27	133.4	1.40	2.43**	42
Mo	1.44	1.51	2.72	1.59	6.14**	42
Mo (sage)	0.61	0.60	0.88	0.71	3.77**	40
B (sage)	30.0	1.53	31.9	1.48	2.46**	41
Org C (%)	1.08	1.58	1.64	1.56	6.22**	42
pH	7.85	0.35	7.79	0.32	1.00	42

Table 5b.   Test Results of Uinta Formation Samples, Group 1
            vs Group 2.

Element	$\overline{X}$ Group1	s	$\overline{X}$ Group 2	s	t Value	DF
Hg	45.0	1.33	43.0	1.38	0.64	56
Zn	70.1	1.42	66.3	1.45	1.11	79
Li	17.3	1.50	17.2	1.46	0.14	79
B	122.0	1.30	121.0	1.32	0.24	79
Mo	1.47	1.47	1.39	1.52	0.97	79
B (sage)	29.2	1.45	30.4	1.43	1.56*	77
Mo (sage)	0.63	0.58	0.59	0.63	0.77	77

Table 5c.   t Test Results, Uinta Formation Samples, Group 1
            vs Group 3.

Element	$\overline{X}$ Group 1	s	$\overline{X}$ Group 3	s	t Value	DF
Hg	45.0	1.33	45.9	1.30	0.27	47
Zn	70.1	1.42	66.4	1.40	1.25	49
Li	17.3	1.50	19.6	1.43	2.89**	49
B (soil)	122.0	1.30	125.0	1.35	0.63	49
Mo (soil)	1.47	1.47	1.58	1.42	0.79	49
B (sage)	29.2	1.45	31.7	1.41	2.78**	49
Mo (sage)	0.63	0.58	0.62	0.61	0.08	49
Org C (%)	1.04	1.50	1.22	1.47	2.13**	49
pH	7.9	0.32	7.6	0.28	3.84**	49

**significant at α = .05
*significant at α = .10

Groups 1-4 are defined in Appendix III pp.95-98.

Table 5d.   t Test Results, Uinta Formation Samples, Group 2
            vs Group 3.

Element	$\overline{X}$ Group 2	s	$\overline{X}$ Group 3	s	t Value	DF
Hg	42.9	1.38	45.9	1.30	0.85	47
Zn	66.2	1.45	66.4	1.40	0.03	49
Li	17.2	1.46	19.6	1.43	2.62**	49
B	121.0	1.32	125.0	1.35	0.68	49
Mo	1.38	1.52	1.58	1.42	1.36*	49
B (sage)	30.4	1.43	31.7	1.41	1.52*	49
Mo (sage)	0.59	0.63	0.62	0.61	0.58	49
Org C (%)	1.02	1.53	1.22	1.47	2.33**	49
pH	7.9	0.33	7.6	0.28	4.87**	49

Table 5e.   t Test Results, Uinta Formation Samples, Group 3
            vs Parachute Creek Member Samples, Group 3

Element	Mean Par. Crk. Samples	s	Mean, Group 3 (Uinta)	s	t Value	DF
Hg	50.1	1.50	45.9	1.30	0.93	39
Zn	73.0	1.35	66.4	1.40	2.46**	42
Li	30.2	1.48	19.6	1.43	4.49**	42
B	133.4	1.40	125.0	1.35	1.31*	42
Mo	2.7	1.59	1.6	1.42	4.11**	42
B (sage)	31.9	1.48	31.7	1.41	0.21	41
Mo (sage)	0.88	0.71	0.62	0.61	3.09**	40
Org C (%)	1.64	1.56	1.23	1.47	3.59**	42
pH	7.8	0.32	7.6	0.28	2.18**	42

Table 5f.   t Test Results, Sagebrush Subspecies Tridentata
            vs Subspecies Wyomingensis.

Element	$\overline{X}$ Tridentata	s	$\overline{X}$ Wyomingensis	s	t Value	DF
Mo (sage)	0.64	0.48	0.67	0.54	0.54	43
B (sage)	30.4	1.50	30.3	1.47	0.11	44
Mo (soil)	1.52	1.53	2.07	1.54	2.73**	45
B (soil)	121.9	1.25	129.2	1.38	1.38*	45

Table 5g.   t Test of Sagebrush Subspecies Wyomingensis on
            Parachute Creek Member vs Subspecies Wyomingensis
            on Uinta Formation.

Element	Wyom. Mean Parachute Crk	s	Wyom. Mean Uinta Fm	s	Value	DF
Mo (sage)	0.94	0.50	0.57	0.61	3.34**	14
B (sage)	30.9	1.36	29.9	1.54	0.74	15
Mo (soil)	3.77	1.40	1.46	1.36	4.58**	16
B (soil)	143.3	1.36	121.7	1.44	2.73**	16

tions over such a small geographic distance. The Uinta
Formation is spread throughout the whole area so artificial
boundaries were created that separated the Uinta Formation
samples into three groups shown in Figures 18 to 20
(Appendix III), where group 1 is in the easternmost part
of the area and groups 2 and 3 proceed westerly. Table 5b
shows a test of group 1 vs group 2. Only boron in sage
shows a difference in means at the α = .10 level. Table 5c
shows the test between group 1 and group 3 on Uinta Formation
(max. geographic separation). In this case, Li, B in sage,
organic carbon, and pH in soils show significant differences.
In Table 5d group 2 vs group 3 Uinta Formation samples are
tested. Li and Mo in soils, B in sage, organic carbon, and
pH have significantly higher means. The means of many com-
ponents in the Uinta Formation are increasing westward.
These trends in the Uinta are most strongly controlled by
organic carbon and pH. Therefore the distinctions are
probably caused chiefly by current climatic differences,
since the western area has higher elevations, more moisture,
and a thicker vegetation cover.

    These climate variations are significant enough to
cause differences within the Uinta Formation and they are
further emphasized by observed differences between the
Parachute Creek member and the Uinta Formation. Table 5e
shows a test of Parachute Creek samples vs Uinta samples

both in the same geographic area (Group 3). All components except Hg and B in sage show significantly higher means in the Parachute Creek member samples. Therefore the two lithologies do have differences in trace elements in their respective soil profiles.

In order to test the appropriateness of the artificial distinctions of groups 1-3 each of the three groups were randomized by random deletions and the t tests were rerun. This was done to minimize the possibility of single sample localities influencing the population means. In all of the randomized tests no differences in t test data were found.

Another test was devised to ascertain whether species differences are apparent in sagebrush. The two subspecies of sage (wyomingensis and tridentata) were tested and Table 5f shows that no significant difference exists in the subspecies even though the B and Mo are significantly different in the soils on which they grew. This suggests that these two subspecies of sage vary little over the study area. Table 5g shows the means of the wyomingensis with respect to differences in lithology. This shows that the B and Mo in the soils of the Parachute Creek and Uinta Formation are significantly different in this test. However, only the Mo shows a significantly different mean in the sage. This, in part, may be due to the fact that it is only a small population (df = 15).

Many inconsistencies exist with respect to the B values in sage. Boron in sage has a high regional component of variance while boron in soil has no regional component of variance. Boron in sage has a negative correlation with organic carbon in the soil but B in soil has a positive correlation with organic carbon in soil. This situation spawns speculation about B in sage. These inconsistencies could be due to a biochemical influence. Table 3 shows that other data from the similar areas list B in the soil as 61 ppm (GM) and in sage as 13 ppm (highest expected value). Since in the vicinity of tract C-a, both the soils and sage are much higher it might be possible that the sage is exhibiting some sort of leveling effect. As the B in soil increases the B in sage increases, but at a slower rate. This could be why B in sage exhibits a regional trend whereas B in soil has none.

The slower increase in boron in sage may be dampening the local variance exhibited by B in soil. This could also be the reason why the B in soil and sage do not correlate well. It must be emphasized that this is speculation and additional studies would be necessary to show any of these relationships conclusively.

Table 6 . Results of Multiple Regression with
B as the Dependent Variable.

Sample Size	253
Dependent Variable	B
Independent Variables	Hg, Zn, Li, Org, pH, Mo
Coefficient of Determination	0.09282
Multiple Corr Coefficient	0.30466
Estimated Constant Term	1.7479070
Standard Error of Estimate	0.10072519

Analysis of Variance
for the Regression

Source of Variation	DF	S. SQ.	M.S.	F	PROB
Regression	6	0.255365	0.425608E-01	4.195	0.0005
Residuals	246	2.49581	0.101456E-01		
Total	252	2.75117			

VAR.	REGRESSION COEFFICIENT	S.E. OF REG. COEF.	F-VALUE OF (1.246)	PROB	CORR. COEFF. WITH B
Hg	0.2364452E-01	0.3833E-01	0.3805	0.5379	0.0262
Li	0.1186452	0.3833E-01	2.863	0.0919	0.1637
Org C	0.364379BE-02	0.4391E-01	0.6888E-02	0.9339	0.0553
pH	0.3552470E-01	0.2311E-01	2.363	0.1256	0.1014
B	-0.4397217E-02	0.7901E-01	0.3831E-02	0.9507	0.0480
MoSo	0.2825871E-02	0.4241E-01	0.4440E-02	0.9469	0.1003
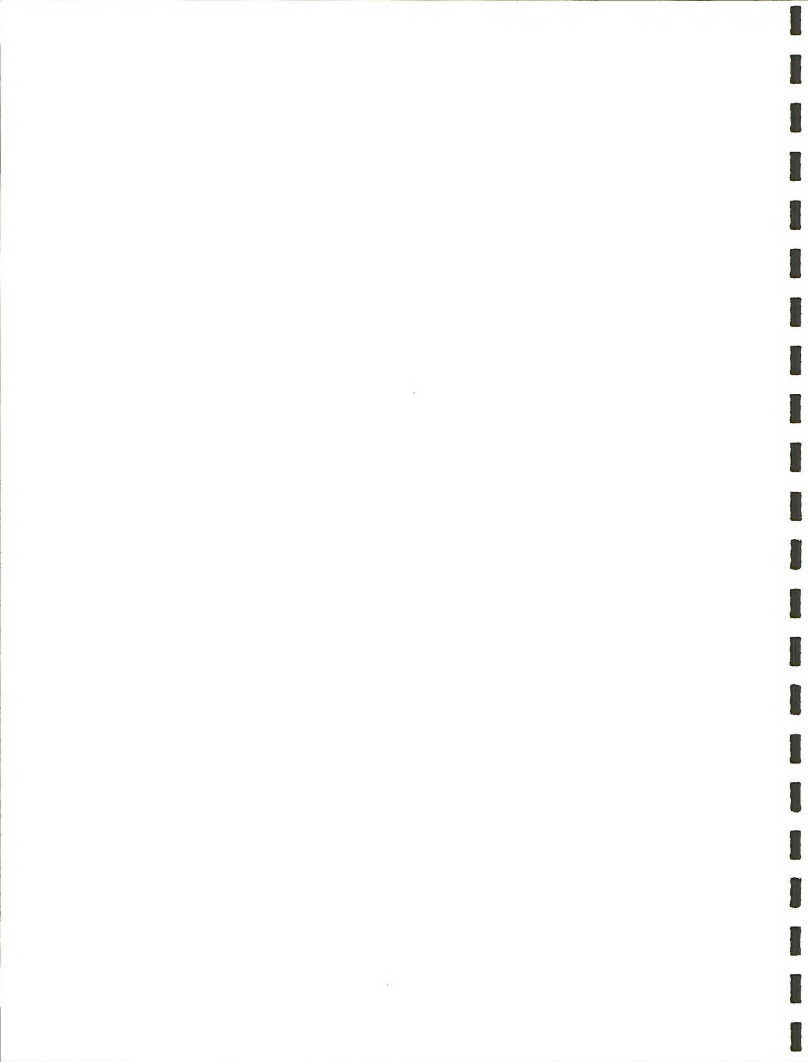
Table 7. Results of Multiple Regression with
Zn as the Dependent Variable.

Sample Size	253				
Dependent Variable	Zn				
Independent Variables	Hg, Li, Org, pH, B, Mo				
Coefficient of Determination	0.03634				
Multiple Corr Coeff	2.19062				
Estimated Constant Term	1.3832824				
Standard Error of Estimate	0.12481431				

Analysis of Variance
for the Regression

Source of Variation	DF	S. SQ.	M.S.	F	PROB
Regression	6	0.144502	0.240837E-01	1.546	0.1638
Residuals	246	3.83234	0.155786E-01		
Total	252	3.97684			

VAR.	REGRESSION COEFFICIENT	S.E. OF REG. COEF.	F-VALUE OF (1.246)	PROB	CORR. COEFF. WITH Zn
Hg	-0.4432343E-02	0.3096E-01	0.2050E-01	0.8863	0.0072
Zn	-0.3184751E-02	0.5145E-01	0.3831E-02	0.9507	0.0480
Li	0.1105455	0.5648E-01	3.832	0.0514	0.2736
Org C	0.5443270E-01	0.3526E-01	2.383	0.1240	0.1710
pH	0.2553415E-01	0.1867E-01	1.871	0.1727	0.0896
MoSo	0.4465163E-01	0.3410E-01	1.714	0.1917	0.2156

Table 8. Results of Multiple Regression with
Mo as the Dependent Variable.

Sample Size	253
Dependent Variable	Mo
Independent Variables	Hg, Zn, Li, Org, pH, B
Coefficient of Determination	0.38820
Multiple Corr Coeff.	0.62305
Estimated Constant Term	-1.2369728
Standard Error of Estimate	0.18765236

Analysis of Variance
for the Regression

Source of Variation	DF	S. SQ.	M.S.	F	PROB
Regression	6	5.49647	0.916078	26.02	0.0000
Residuals	246	8.66250	0.352134E-01		
Total	252	14.1590			

VAR	REGRESSION COEFFICIENT	S.E. OF REG COEF.	F-VALUE OF (1.246)	PROB	CORR. COEFF. WITH Mo
Hg	0.7158407E-01	0.5749E-01	1.550	0.2143	0.1192
Zn	0.6387511E-02	0.9586E-01	0.4440E-02	0.9469	0.1003
Li	0.9662530	0.8630E-01	125.4	0.0000	0.6047
Org C	-0.1604181	0.6521E-01	6.051	0.0146	0.1432
pH	-0.3127205E-01	0.3486E-01	0.8049	0.3705	0.0051
B	0.1549777	0.1184	1.714	0.1917	0.2156
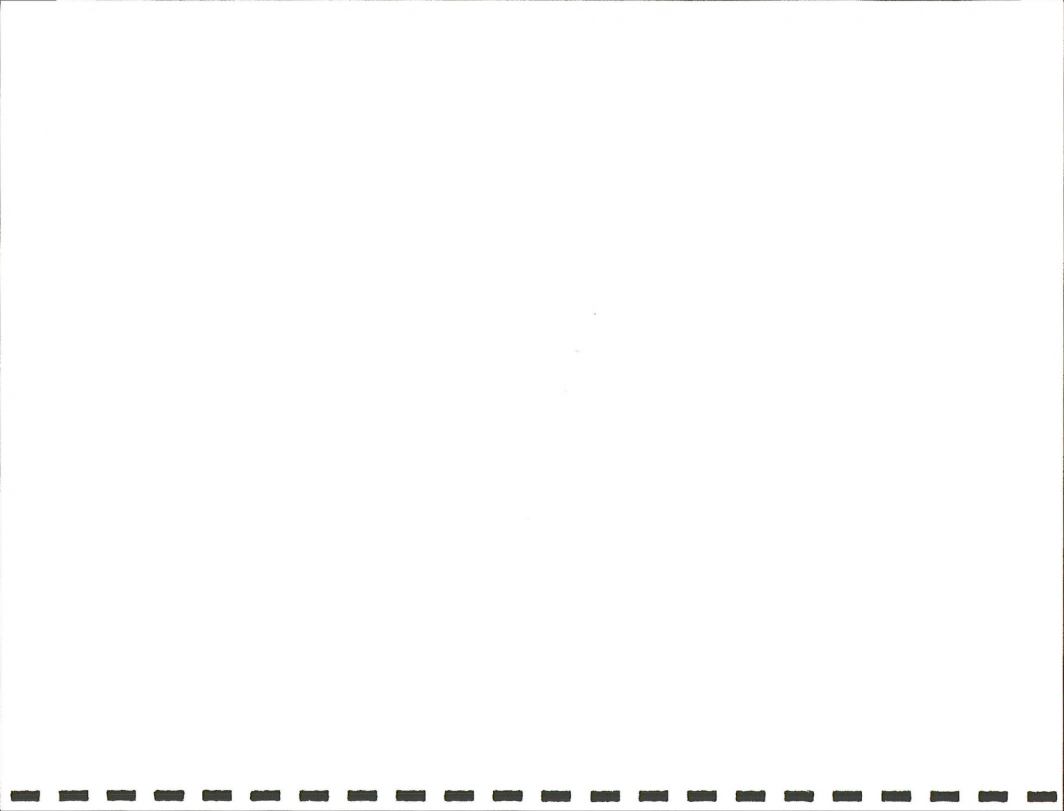
Table 9. Results of Multiple Regression with
Li as the Dependent Variable.

Sample Size	253
Dependent Variable	Li
Independent Variables	Hg, Zn, Org, pH, B, Mo
Coefficient of Determination	0.49132
Multiple Corr. Coeff.	0.70094
Estimated Constant Term	0.36804895
Standard Error of Estimate	0.11283737

Analysis of Variance
for the Regression

Source of Variation	DF	S. SQ.	M.S.	F	PROB
Regression	6	3.02526	0.504210	39.60	0.0000
Residuals	246	3.13214	0.127323E-01		
Total	252	6.15740			

VAR.	REGRESSION COEFFICIENT	S.E. OF REG. COEF.	F-VALUE OF (1.246)	PROB	CORR COEF WITH Li
Hg	0.8781140E-02	0.3467E-01	0.6413E-01	0.8003	0.0919
Zn	0.9696773E-01	0.5731E-01	2.863	0.0919	0.1637
Org C	0.2418713	0.3657E-01	43.73	0.0000	0.3955
pH	0.4486958E-01	0.2080E-01	4.654	0.0319	0.0766
B	0.1387339	0.7087E-01	3.832	0.0514	0.2736
Mo	0.3493725	0.3120E-01	105.4	0.0000	0.6047

Parachute Creek
member of Green
River Formation

Tu

Uinta Formation

N
15°
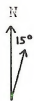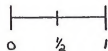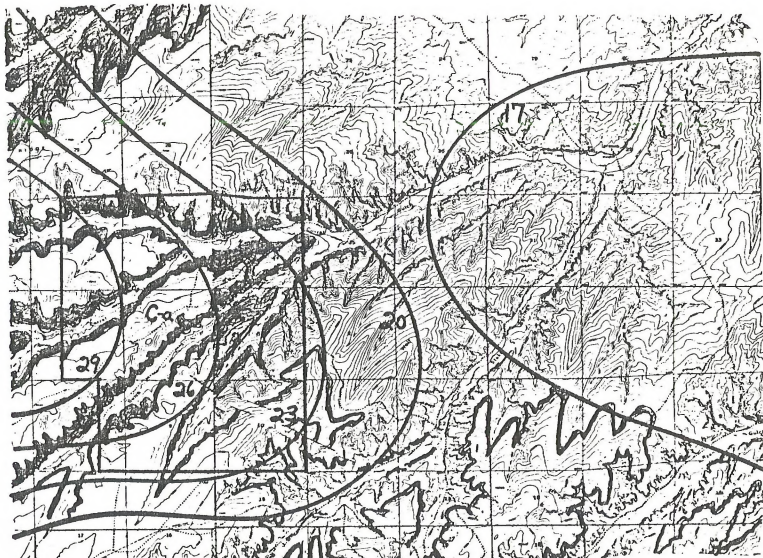
Contour Interval 3.0 ppm Li

0   ½   1

Miles

Figure 10. Trend Map of Li in all
Soil Samples. (degree=3)

N
↑ 15°

T 2009

[Tu 1985] Parachute Creek member of Green River Formation

[Tu] Uinta Formation

Contour Interval 2.0 ppm Li

|———|———|
0   ½   1
Miles
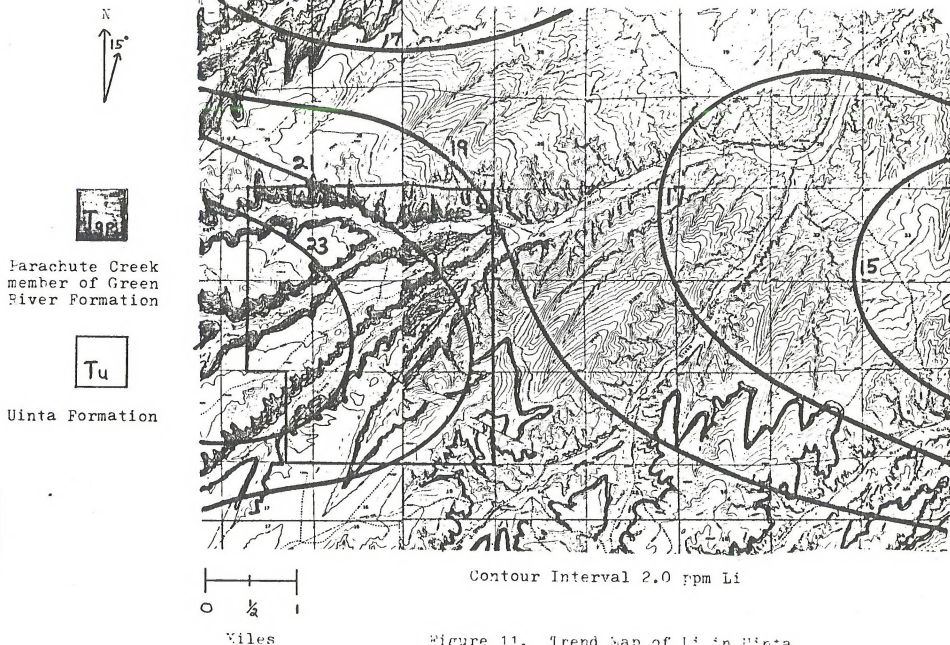
Figure 11. Trend Map of Li in Uinta Formation Soil Samples. (degree=3)

N
15°

Parachute Creek member of Green River Formation

Tu

Uinta Formation

Contour Interval 0.2% Organic Carbon

0
½
1
Miles
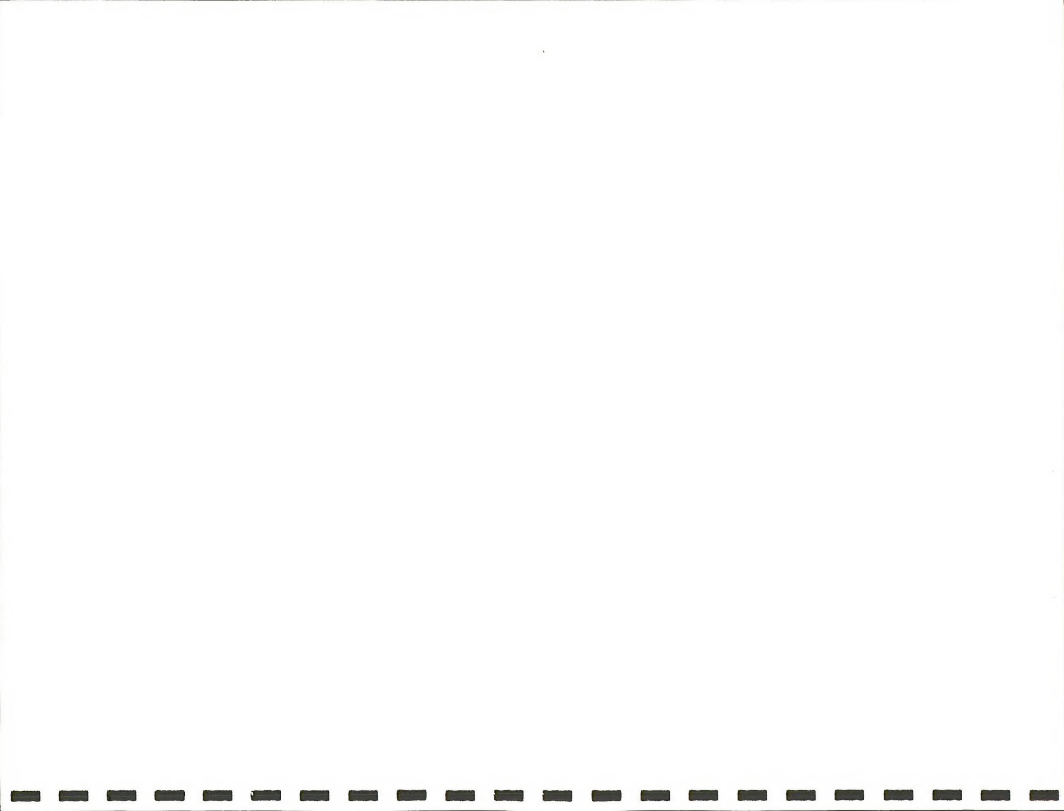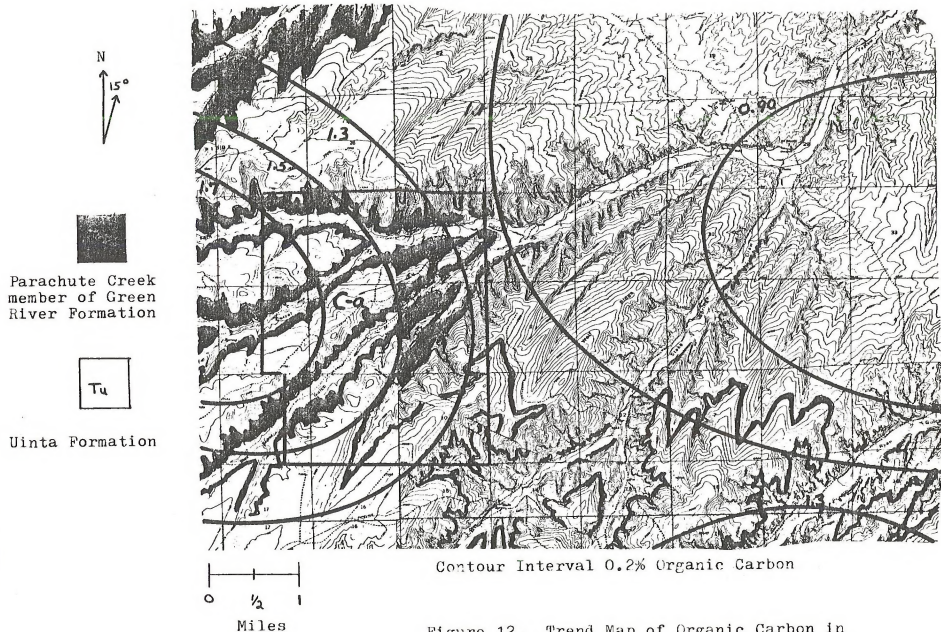
Figure 12. Trend Map of Organic Carbon in all Soil Samples. (degree=3)

N
15°

T9R

Parachute Creek
member of Green
River Formation

Tu
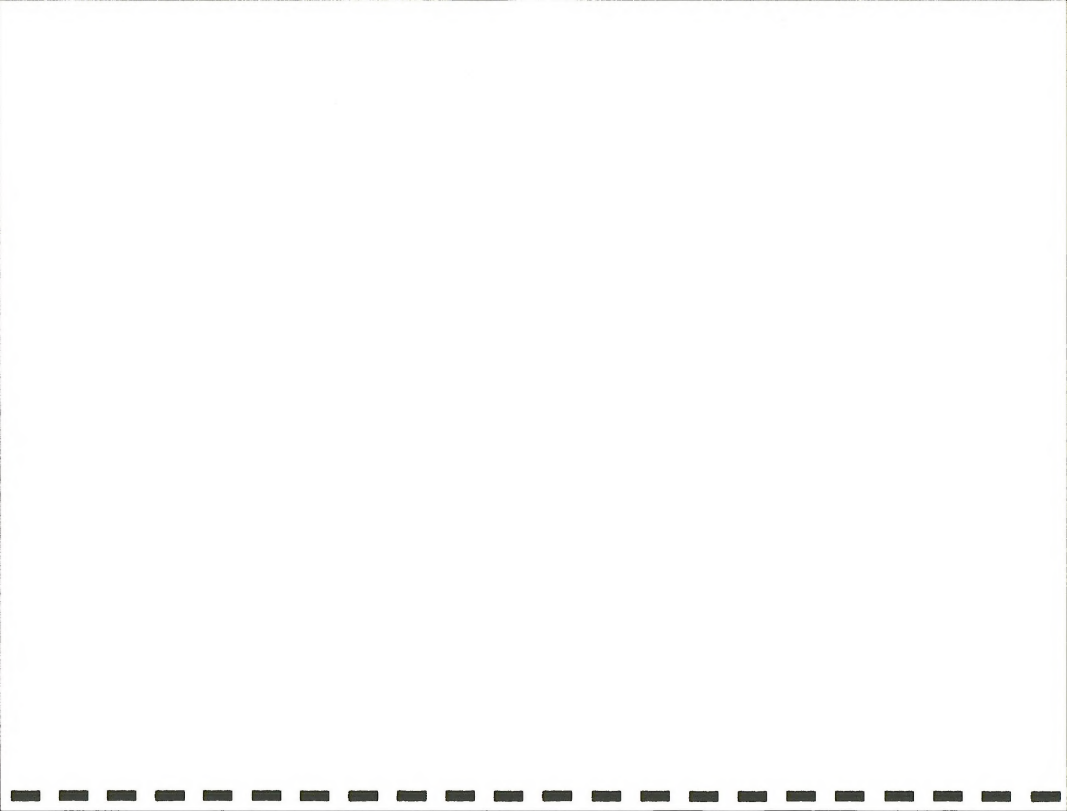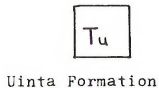
Uinta Formation

Contour Interval 0.3 ppm Mo

Figure 13. Trend Map of Mo in all Soil Samples.
(degree=3)
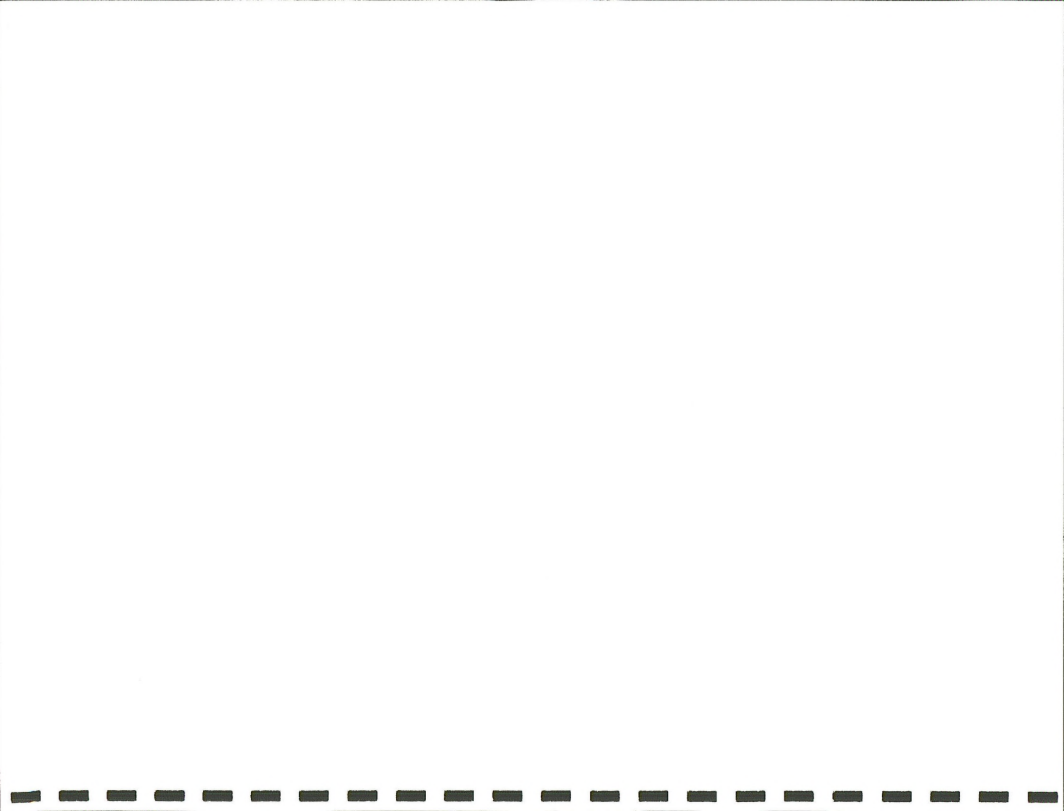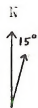
0   ½   1
Miles

N
↑15°

Parachute Creek
member of Green
River Formation

Tu
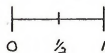
Uinta Formation

Contour Interval 0.2 ppm Mo

0   ½   1

Miles

Figure 14. Trend Map of Mo in Uinta
Formation Soil Samples. (degree=3)

N
15°

T9R

Parachute Creek
member of Green
River Formation

Tu
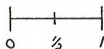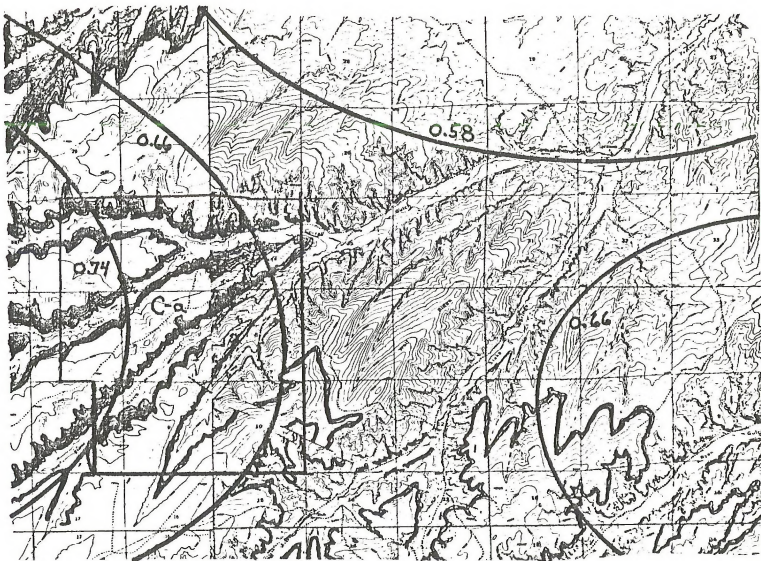
Uinta Formation

Contour Interval 0.08 ppm Mo

0   ½   1
         Miles

Figure 15.   Trend Map of Mo in All
Sagebrush Samples. (degree=2)
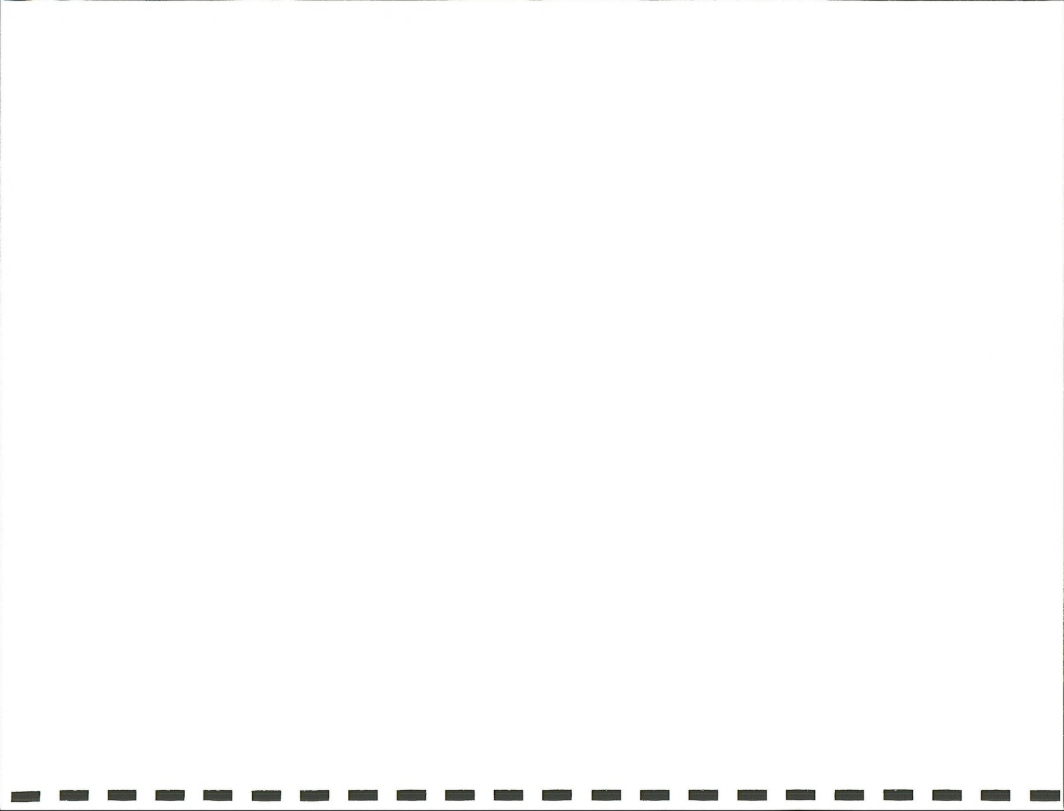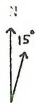
Parachute Creek
member of Green
River Formation

Tu

Uinta Formation

30

28

26

24

Ga
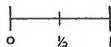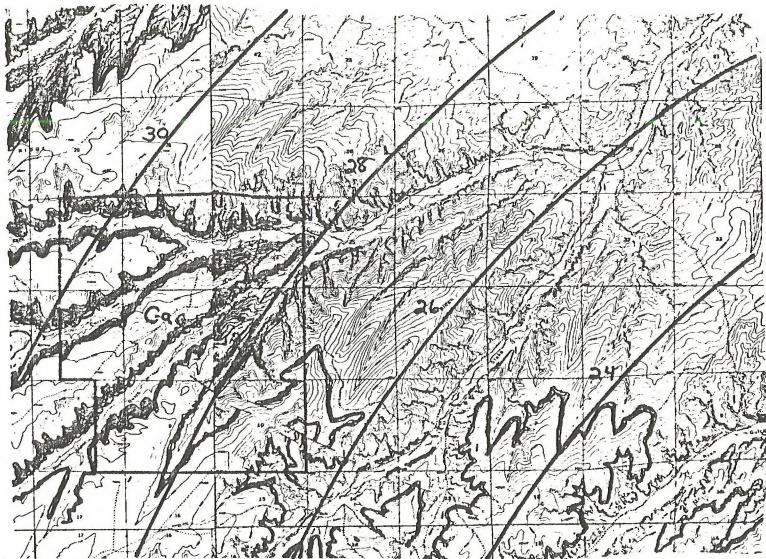
Contour Interval 2.0 ppm B

N
15°

0   ½   1
Miles

Figure 16. Trend Map of B in Sagebrush Samples.
(degree = 1)
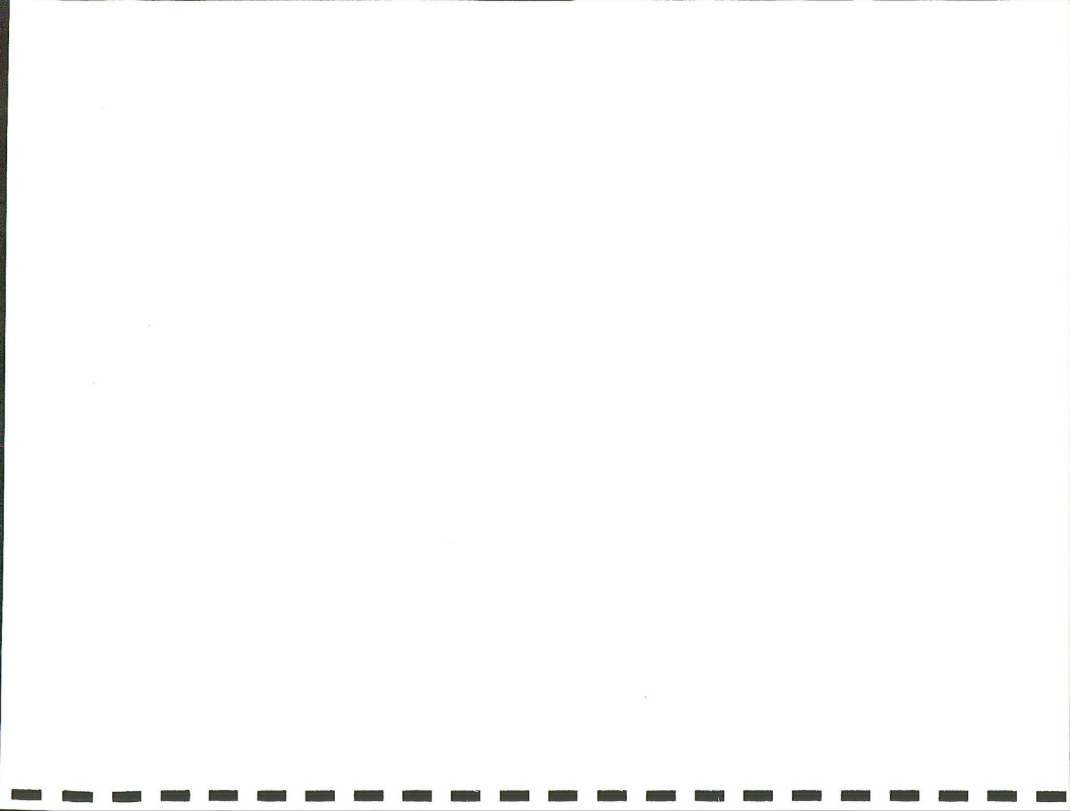
Table 10. Trend Surface Analysis
Statistics.

Element	Trend Degree	F-value	R^1
Li	3	$10.9*(10,242)$	0.56
Li(Uinta)	3	$7.3*(10,199)$	0.52
Mo	3	$6.2*(10,242)$	0.35
Mo(Uinta)	3	$2.8*(10,199)$	0.36
B(sage)	1	$4.17(2,237)$	0.20
Organic Carbon	3	$6.1*(10,242)$	0.45
Mo(sage)	2	$2.0*(6,236)$	0.22

* Significance at $\alpha = 0.05$

[1] Multiple Correlation Coefficient is equal to the square root of the percent sum of squares explained by the regression.

Other Data Reduction Techniques

Multiple regressions (Tables 6-9) were also run with the important components as dependent and alternately as independent variables. These serve to further illustrate and clarify the correlations between the variables. The only statistically significant regressions were for the dependent variables Li, B, and Mo in the soils with the greatest influence being organic carbon, especially in the Li regression. The independent variables from the soil data were B, Hg, Zn, Li, organic carbon, and pH.

Trend surface analyses pictorially display (Figures 10-17) the analysis of variance results on the sample grid. For elements with no regional variance the trend surfaces are random noise. Contour intervals were chosen by dividing the range of values for each component by an integer, whose value depends on the regional variation shown. The greater the range and regional component, the more contour intervals can be shown. The trend maps for Li, Mo, and organic carbon in soils show statistically significant trends when the lithology differences are not taken into account. When only the samples taken on the Uinta Formation are mapped, Li, Mo, and organic carbon in the soils still show significant trends. Thus a regional trend is displayed in the Uinta Formation from east to west with increasing concentrations toward the west. This trend is enhanced by the lithologic control of

the Parachute Creek member. The Mo and B in the sage do not exhibit 95% confidence in their trend surfaces but they are very similar to the soil trends (Table 10).

Previous work in the Piceance Basin (Ringrose et al, 1976b) suggested that the regional trends of Li and Zn were north to south with higher concentrations in the south and west. This study indicates that in the tract C-a area the trend has a significant east-west component. The trend of Zn was statistically insignificant, thus it seems that for Zn the trend is broader and encompasses a larger area than was sampled in this study.

CONCLUSIONS

A geochemical baseline study of soils and plants from
oil shale tract C-a and vicinity shows that the elements
As and B are elevated with respect to normal soils. These
elements may pose environmental hazards as the development
of the oil shale industry proceeds. The elements Zn, Li,
Mo, and Hg are present in average concentrations. The
geometric means of Li and Mo show no significant difference
from crustal averages but when only the samples from the
Parachute Creek member are considered, Li and Mo are ele-
vated. These elements are potentially toxic during the
storage of raw shale and as airborne pollutants from retort-
ing processes. The analysis of plant materials (big sage,
Western wheatgrass, Indian ricegrass) show correlations with
the soils from which they are derived. Mo is not elevated
in sage compared to other areas but the B is substantially
higher in soils and sage than the Piceance Basin as a whole.

Statistical analysis of means show that there is a
difference between the soils and plants on the Uinta Forma-
tion as opposed to the Parachute Creek member. Most of the
surficial materials show significantly higher values in the
Parachute Creek member. Hypothesis tests also indicate that
there is no significant difference in the sage subspecies
Artemisia tridentata wyomingensis and tridentata.

The limited data from the rice grass and wheat grass show enrichment in Mo and B. Future studies would benefit by additional analyses of these important forage materials.

Regional trends with increasing concentrations from east to west are displayed within the study area for Li, Mo, and organic carbon in soils and B and Mo in sage. These trends are evident in the soils developed on the Uinta Formation. The regional trend is enhanced by lithologic variations. Variations in the lacustrine environment of ancient Lake Uinta are likely the cause for these regional variations, since the study area is not located in the center of the Piceance Basin.

The sampling design was sufficient to describe most of the important variation in the environment. Composite sampling decreased the low level variance, but for some components the local variance is still dominant suggesting that over short geographic distances the area may seem heterogeneous but in most cases the actual deviations are minimal.
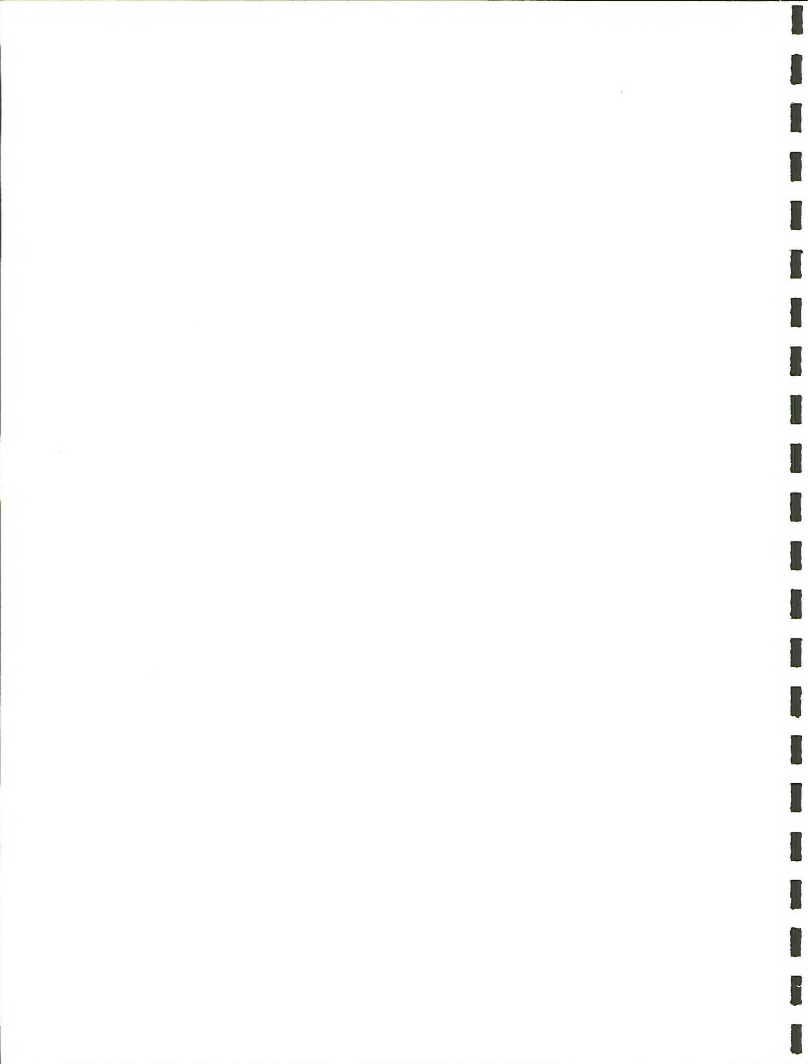
APPENDIX I

Sample Preparation

Each soil sample consisted of approximately 200 grams. The whole sample was repeatedly split with a riffle splitter until about 10 grams remained. The splitting was done to avoid analytical errors caused by stratification of soil components during transport. The 10 gram split was then ground for about 8 minutes in a tungsten carbide vial with a leucite sleeve by a Spex mixer mill.

Plant samples were allowed to dry at ambient laboratory temperatures. The wheat grass and rice grass were washed with distilled water in an ultrasonic bath. The grass samples again were allowed to dry for three days. The washing procedure was carried out to remove soil from the grass caused by rain splash. The sage samples were not washed because only new growth was sampled from upper parts of the bush where rain splash and wind blown soil do not appear to be significant. All the plant samples were ground in a commercial blender. The sage was ground finely while the grasses remained somewhat coarser. After grinding the samples were dried at $70^{o}C$ for 24 hours.

Analyses were performed on all sage samples but only on analysis of variance wheat grass and rice grass because collection ratios of the grasses tended to be low, especially

for the wheat grass. All samples were randomly chosen for
analysis to avoid any non-random analytical errors. Random-
ization is necessary because non-random analytical errors
could contribute to regional variations while analyzing
samples from a specific geographic area.

   To analyze for Hg, Zn, and Li in the soil and plant
samples approximately 1 g of sample was digested with 5:1
perchloric-nitric acid for 3 hours at a constant temperature
of 95°C. Each sample was diluted to 50 mls and mixed
thoroughly. The Hg analysis was carried out immediately
after cooling to avoid losses of this volatile component.
Zn and Li were analyzed from the same digestion on the
following day. The flameless Hg method (Hatch and Ott,
1968) has a sensitivity of about 20 ppb in 1 g of soil. A
dilute solution of stannous chloride is added to an aliquot
of the sample to reduce the mercury to the elemental vapor
state. The vapor is then forced through a quartz tube
positioned in the beam path. The absorption is recorded on
a strip chart and compared to standards. All atomic
absorption analyses were performed on a Perkin-Elmer Model
303 atomic absorption spectrometer.

   The Zn and Li analyses are performed by normal atomic
absorption methods. It should be emphasized that all
determinations are total concentrations from bulk, not
laboratory sieved fractions.

pH and Organic Carbon Analysis

The pH was determined by preparing a saturation paste using the bulk soil sample and distilled water. A combination pH electrode was immersed in the sample and a reading is made. Problems with this method arise because soils with varying grain size and clay content may require different amounts of water necessary to form a paste. This causes fluctuations in the observed pH.

Organic carbon was determined by the Walkley-Black Method (American Society of Agronomy, 1965). Ground and accurately weighed samples of soil were suspended in 10 ml of 1.000N K_2CrO_7. Twenty ml of concentrated H_2SO_4 were added to each sample and the solutions were allowed to cool for 1/2 hour. The solutions were diluted to 200 ml with distilled water. A titration with 0.500N $FeSO_4$ was done using O-phenanthroline indicator. The endpoint is reached when the dark green color changed to maroon. If 75% of the K_2CrO_7 was reduced by the soil then the determination is repeated using less sample. The percent organic carbon is found by:

$$\text{Organic Carbon} = \frac{M_{eq}K_2CrO_7 - M_{eq}FeSO_4 \times 0.3}{\text{grams of dry soil}} \times 1.33$$

Problems in Analysis

Many problems were encountered with the Hg analysis. The concentrations in the soils are very low and many were
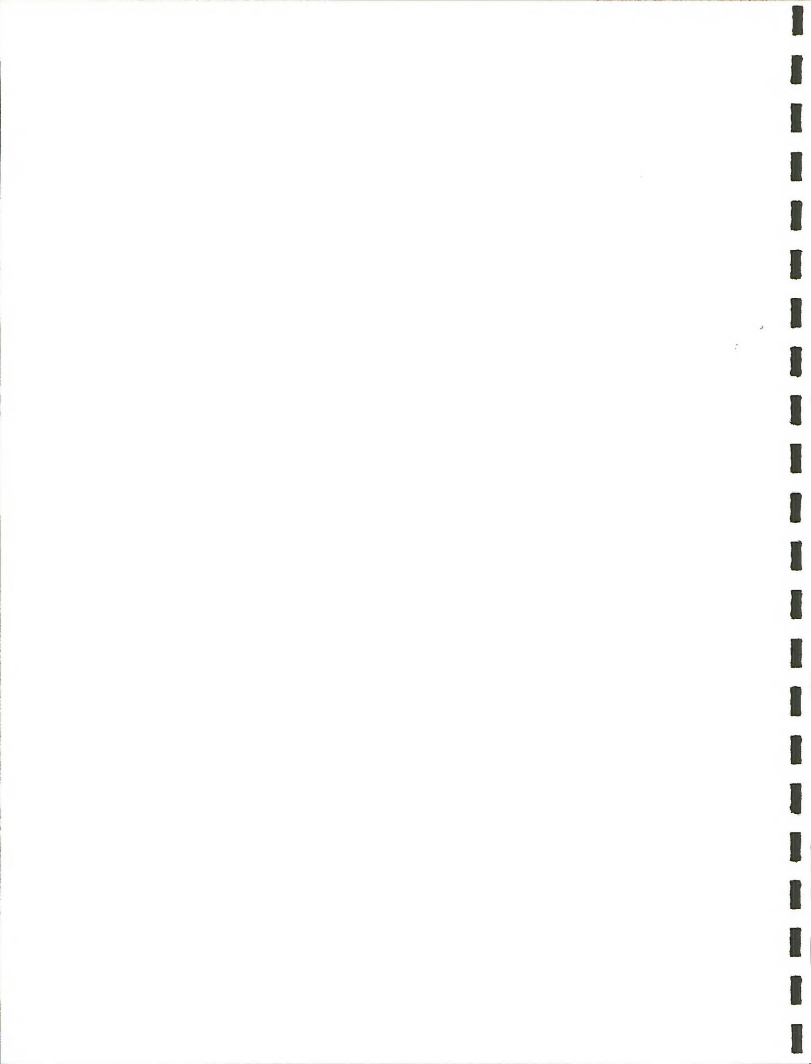
below the detection limit. The standards used in the
analysis were not stable for the lower concentrations and
had to be prepared every 2 hours because of Hg loss. The
solutions were somewhat stabilized with HNO_3.

The analysis of plant material was difficult with
perchloric digestions. Hg could not be determined in sage
samples because the reaction of perchloric acid with the
finely ground sage was too rapid and violent resulting in
loss of Hg. In the sage determinations it is suggested that
the nitric acid be allowed to oxidize the sample overnight
and then add dilute perchloric acid until the ratio is 5:1.
This may yield better results.

Cadmium was also determined in all of the soil samples
but the results seemed too high. Some random analysis for
calcium were done and the results compared with Cd. There
was a high correlation and the Cd results are probably being
influenced by the known Ca interference. Since the proper
equipment was not available for background correction the Cd
results were discarded. Li was reliable in soil analyses
but absorbance could not be distinguished from noise in all
the plant samples.

<u>Boron and Molybdenum Analyses</u>

B and Mo analyses were done at Project Central Analytical
Facility (Meglen, 1977). Soil samples were analyzed for B
by the following method.
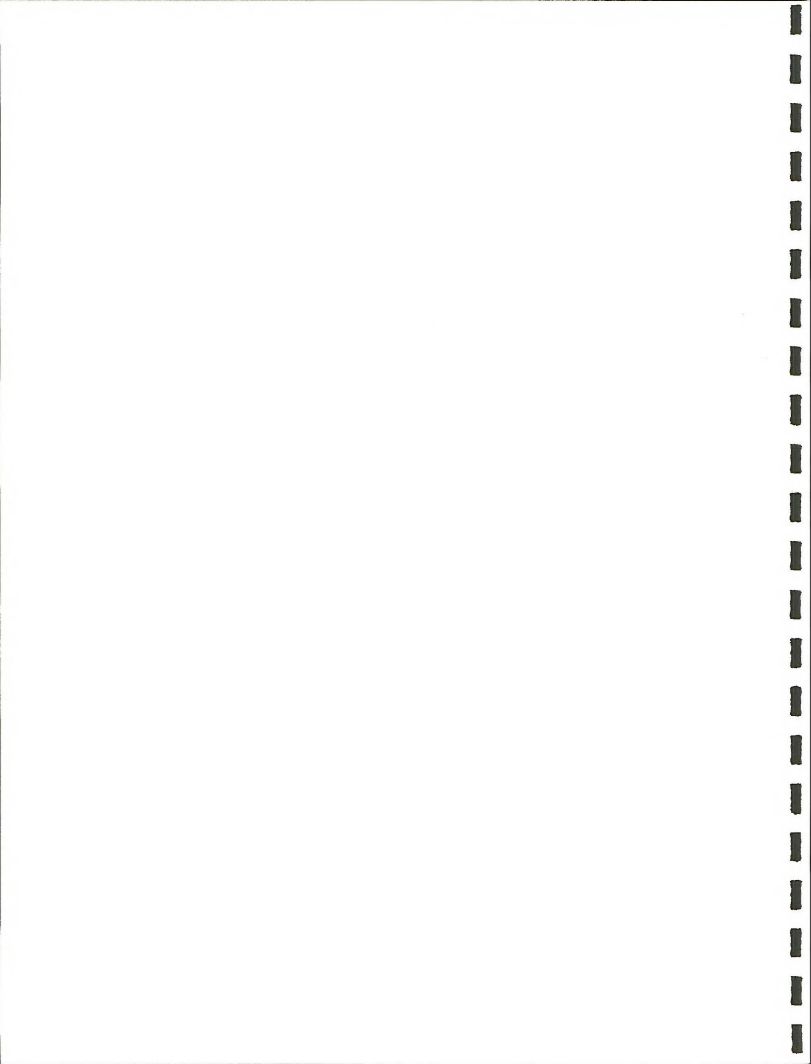
A 1 gram sample was fused with 2 grams Na_2CO_3 in a platinum crucible at $1000^\circ C$ for 1/2 hour. This was cooled and dissolved in HCl and diluted to 50 mls. All labware used was polyethylene to avoid contamination from B in glassware. A 1 ml aliquot is buffered with ammonium acetate EDTA solution to a pH of 4.5. The analysis is done colorimetrically with Azomethine-H at 429 nm on a Perkin Elmer spectrophotometer. The analytical error is 5-10%.

Mo in soils was determined by placing a 1 gram sample in a 100 ml teflon beaker and adding concentrated HNO_3, H_2SO_4, and HF. The solution is evaporated to dryness at $240^\circ C$. This process is repeated until the residue is white. One ml of HCl is added with 4 mls of deionized H_2O. The solution is filtered and thiocyanate solution is added. The analysis is done by atomic absorption using a nitrous oxide-acetylene flame.

The B and Mo in plants was determined by ashing 3.00 grams at $450^\circ C$ for 24 hours, and carrying out analyses similar to the soils, except that Mo was determined colorimetrically in plant samples.
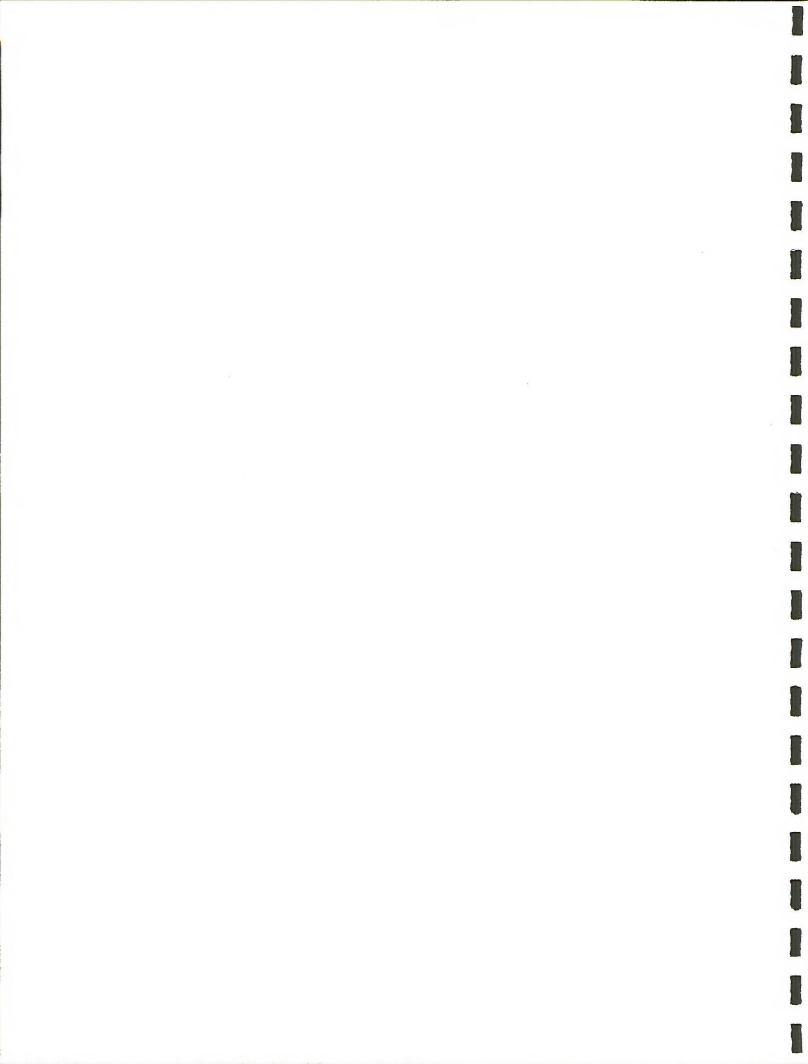
APPENDIX II

Geometric Means and Deviations

Geometric means are calculated using standard techniques on log (base 10) transformations of data except for pH values which are already log values. The geometric deviations are analagous to standard deviations of log transformed data.

In the case of Hg, part of the data are below detection limit so the data set is described as censored (Miesch, 1976a). The detection ratio is the number of determinations above the detection limit (20 ppb for Hg) divided by the total number of samples. For Hg the detection ratio is 222/253 = 0.88. The adjusted mean is found by:

$$\overline{X} = \overline{X}' - \lambda(X - X_o)$$

The adjusted deviation is found by:

$$s^2 = (s')^2 + \lambda(\overline{X}' - X_o)^2$$

where X and s are the mean and deviation of the uncensored data and X is the detection limit.

Lambda is determined graphically (Cohen, 1959). This method reduces the uncertainty in the calculation of mean and deviation. Dropping the less than samples yields, X = 46.6 ppb and s = 1.56. The censored calculation values are X = 43.3 ppb and s = 1.4.

Further adjustments can be made to geometric or standard deviations to subtract out the deviation caused by analytical variability.

The adjusted geometric deviation (GDn) is calculated by:

$$GD_n = \sqrt{(GD)^2 - (GE)^2}$$

where GE is the geometric error. The geometric error is found by calculating the geometric deviations of all analytical replications (see computer program Var (Table 16 in Appendix III). The geometric error is the average of all the geometric deviations for replications.

The use of geometric deviations is most important in determining 95 percent confidence intervals for each element. All the ranges in Table 2 have been calculated using GD_n rather than GD. This narrows the range and gives a more realistic estimate of element concentrations.

The 95% expected range is found by:

$$[\frac{GM}{(GD_N)^{1.96}}] \text{ to GM to } [GM \times (GD_N)^{1.96}]$$

where 1.96 is commonly rounded to 2.0. This states that 95% of the samples determined by this study or any other in this area, should lie in that range (assuming analytical methods used are similar in detection limit and sensitivity).

Analysis of Variance Calculations

The computer program Nest (Table 15, Appendix III) was used to determine the estimated components of variance at each level of the nested or hierarchial model. The problem in the interpretation of these results are in expressing the validity or confidence in the estimated variance compon-

ent. Since the regional component is the most important

tests of the significance of the estimates are needed. The

standard test is the F-statistic value. As can be seen by

inspection of results very few of the highest level vari-

ance components are significant at the 95% level. This

means statistically that it cannot be proven that the com-

ponent is different from zero. This problem arises because

of the distribution of the degrees of freedom in the nested

model. None of the first levels (>1.6 km) have more than

three degrees of freedom. This means the F-value has to be

very large if the variance is to be significant. Since the

only way to increase the degrees of freedom at the highest

level is to collect many more samples and hence make the

cost of the study prohibitive. The values of variance are

accepted as the best estimates available.

Techniques are available (Miesch, 1976b) to assess the

usefulness of variance components. The variance ratio

$$V = \frac{N_v}{D_v} = \frac{s_a^2}{s_b^2 + s_c^2 + s_d^2 + s_e^2}$$

is used to determine the efficiency of a sample design. N_v

is the variance between units (sections) and D_v is the

variance within units. With the variance ratio, the effec-

tive number of samples collected at random (N_r) can be

determined graphically (Miesh, 1976b). With N_r, the maximum

permissible error variance of the means can be calculated:
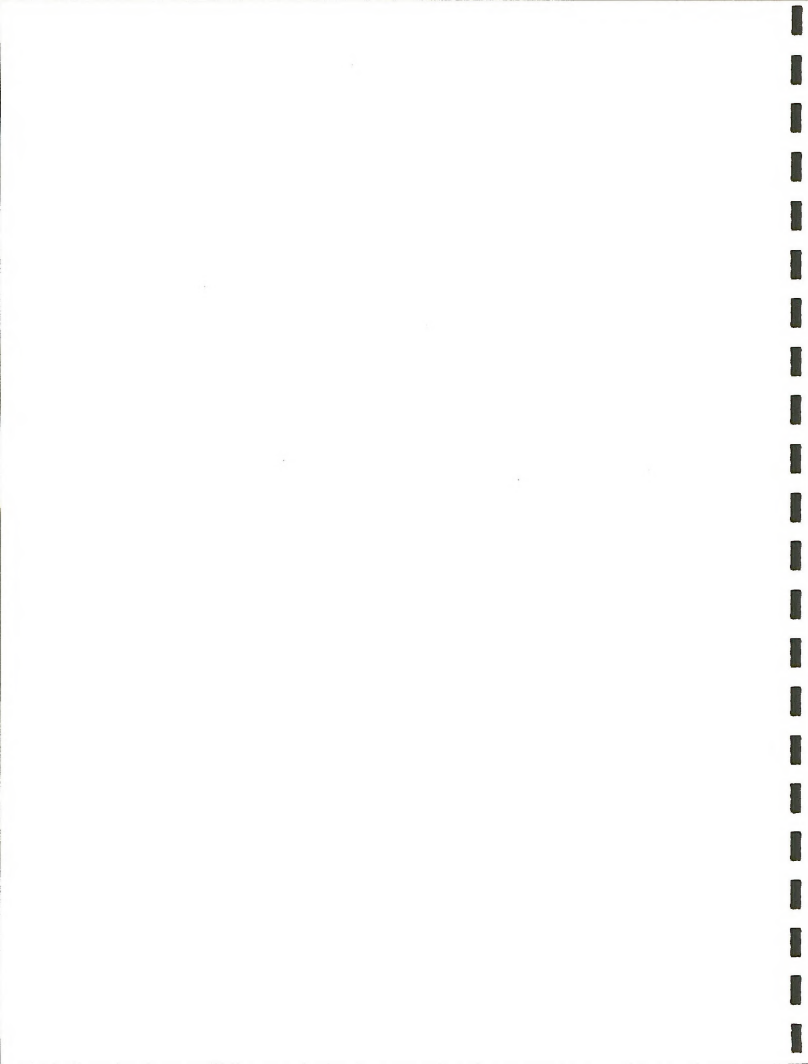
$$E_r = \frac{s_b^2 + s_c^2 + s_d^2 + s_e^2}{N_r}$$

The E_r refers to a balanced design, the maximum error variance for a nested design is given by:

$$E_s = \frac{s_b^2}{N_b} + \frac{s_c^2}{N_b \cdot N_c} + \frac{s_d^2}{N_b \cdot N_c \cdot N_d} + \frac{s_e^2}{N_b \cdot N_c \cdot N_d \cdot N_e}$$

where N_b is the number of randomly sampled areas within each section and so forth for N_c, N_d, N_e.

Another useful quantity is the variance mean ratio (V_m),

$$V_m = N_V/E_s$$

for a non-hierarchial design E_r is used in place of E_s.

At this point an example of these calculations is necessary. For molybdenum in soils the computations are:

$$s_a^2 = 0.01485 \qquad s_d^2 = 0.0159$$

$$s_b^2 = 0.0 \qquad s_e^2 = 0.00273$$

$$s_c^2 = 0.04625$$

The variance ratio (V) is,

$$V = \frac{0.01485}{0 + 0.04685 + 0.0159 + 0.00273} = 0.23$$

from graphs $N_r = 4$

$$E_r = \frac{0 + 0.04625 + 0.0159 + 0.00273}{4}$$

E_s is found by:

$$E_s = \frac{0.01485}{4}(.91) + \frac{0}{4 \cdot 8} + \frac{0.04625}{4 \cdot 8 \cdot 16}(.98) + \frac{0.0159}{4 \cdot 8 \cdot 16 \cdot 32}$$

$$+ \frac{0.00273}{4 \cdot 8 \cdot 16 \cdot 32 \cdot 6}$$
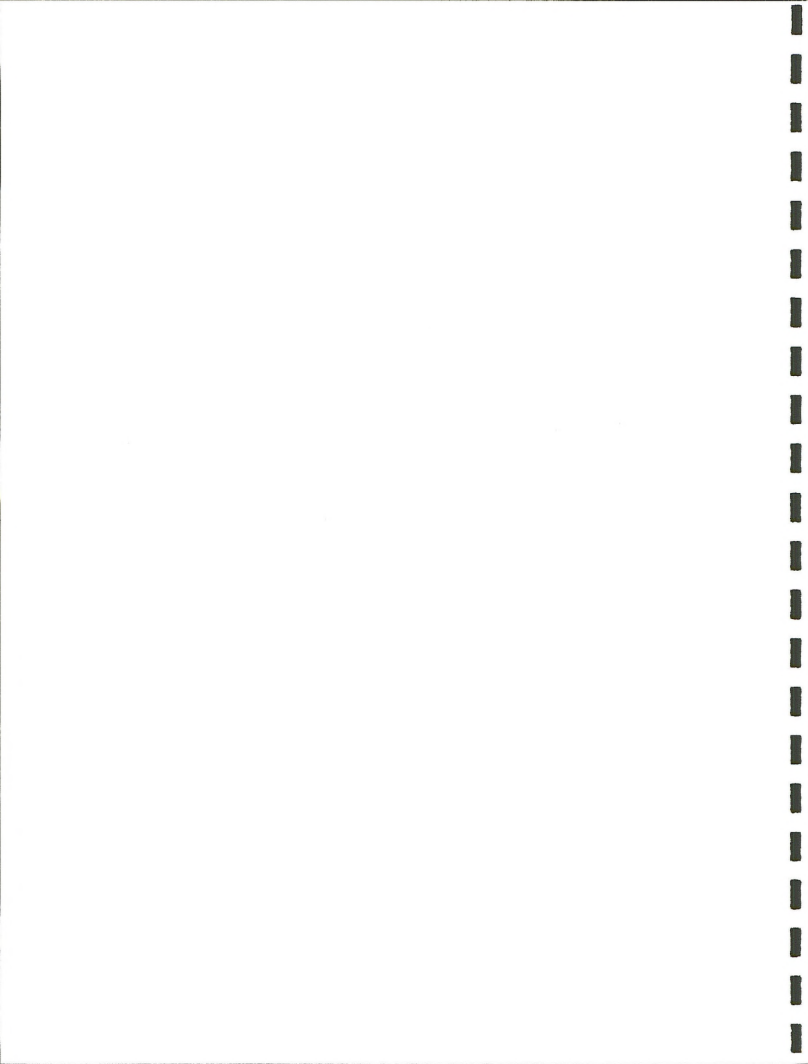
$$E_s = 0.0035$$

where 0.91 and 0.98 are correction factors explained in Miesh (1976a). The variance mean ratio (V_m) is:

$$V_m = \frac{0.01485}{0.0035}$$

$$V_m = 4.28$$

From experience and computer simulation studies it has been shown (Miesh, 1976b) that if E_r is greater than E_s then the model produces at 80% confidence the variance between the studied units (sections). The 80% is derived from the graphs of N_r. In other words if the maximum error of the nested design (E_s) is less than the maximum error variance of a balanced design (E_r) then the model chosen significantly displays the differences in the study area. These same calculations can also be used to determine the most efficient sampling design to describe variance not described by a pilot or initial sampling study. If it was found that $E_s > E_r$ for many components, then the E_s expression could be altered until the observed error variance was acceptable.

The variance mean ratio (V_m) serves as a measure of the stability or reproducibility of a geochemical map. If V_m = 1 basic differences can be shown, if $V_m > 3$ then the resulting map should be quite stable (Miesh, 1976b). As can be seen in Table 2, all the V_m values are greater than or equal to 2.9 and almost all the E_s values are less than E_r. This
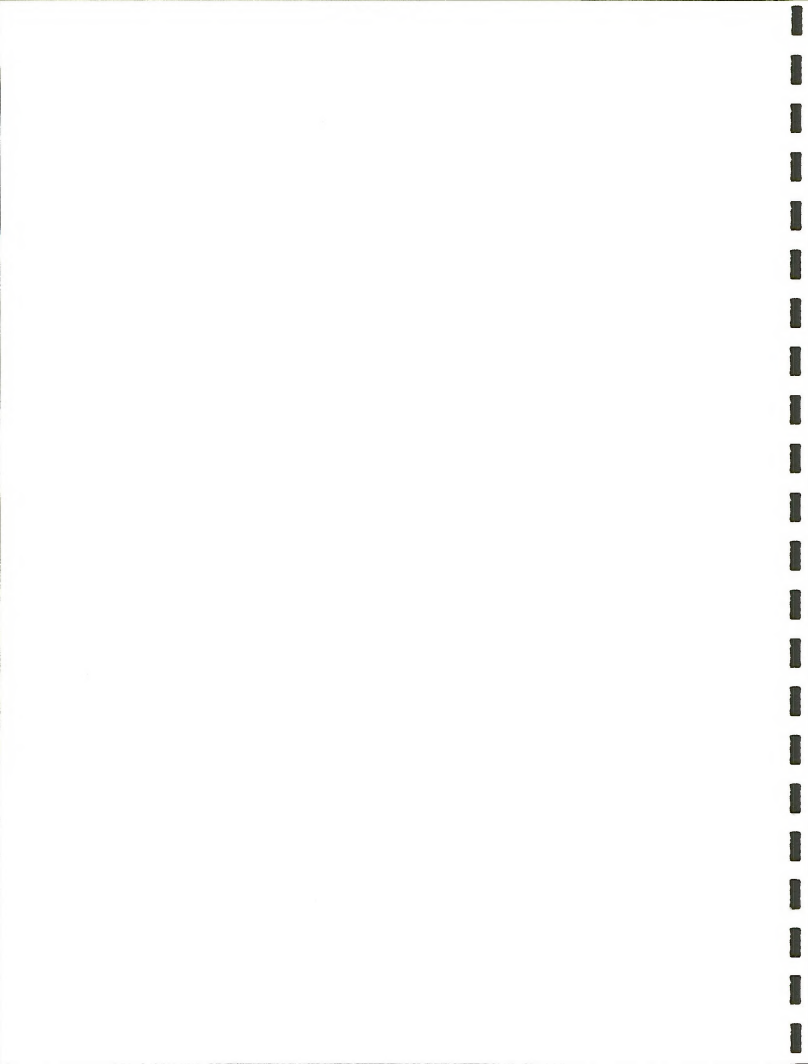
concludes that the sample design was sufficient to describe
the variance between units and that the maps should be very
stable.

Student's t Test

To determine the significance of differences between
two means the Student's t test is used:

$$t = \frac{\overline{X}_1 - \overline{X}_2}{\frac{(s_1)^2}{N_1} + \frac{(s_2)^2}{N_2}}; \quad r = \frac{(s_1^2/N_1 + s_2^2/N_2)^2}{\frac{(s_1)^2/N_1}{N_1-1} + \frac{(s_2)^2/N_2}{N_2-1}}$$

This does not account for differences in variances for
each population tested, which is not of great concern with
the data in this study. Student's t test data show high
significance in many of the populations studied.

Other Data Reduction Techniques

Linear correlation coefficients are calculated for the
log (10) transformed data. Log transformation is necessary
because the parts per million data would give spurious
correlations due to excessively high and low values in the
population.

Multiple regression analyses were also run on the data
to determine how each element varies with the other para-
meters. Trend surface analyses were also done to display
regional and lithographic influences over the grid area.
The correlation coefficients, regression analyses, and trend
surface analyses results are supportive of each other in the
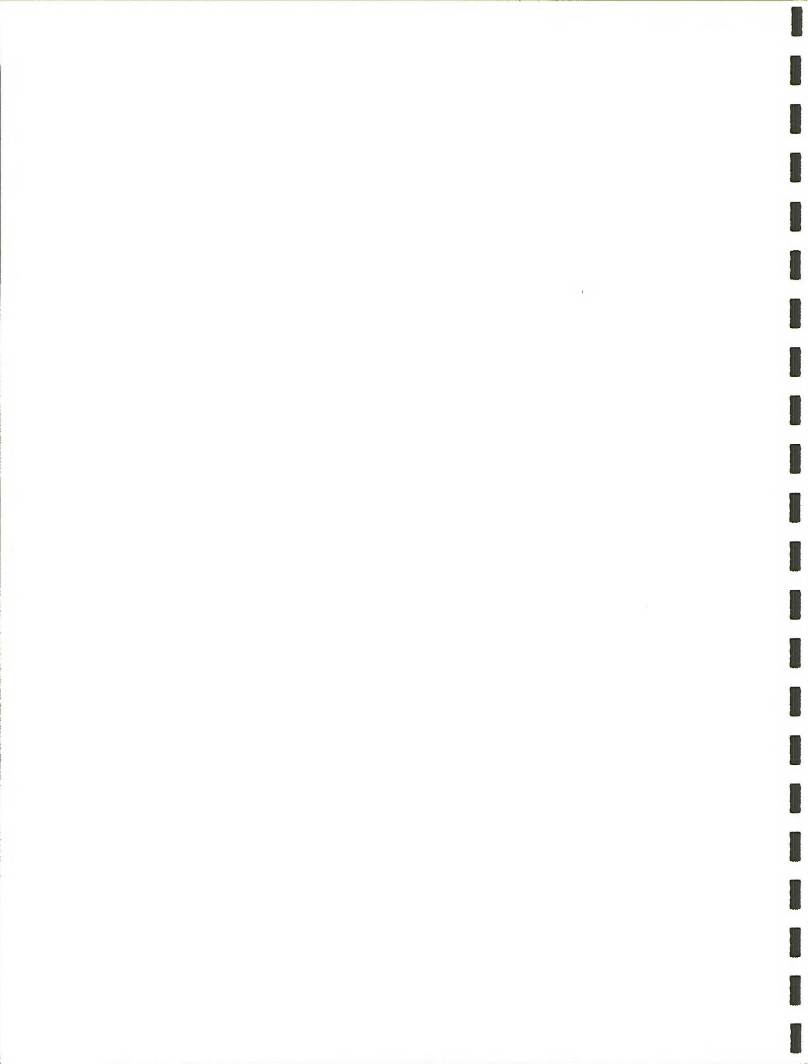
interpretation of the data. All three of the above methods
were performed on library computer programs at the Colorado
School of Mines.
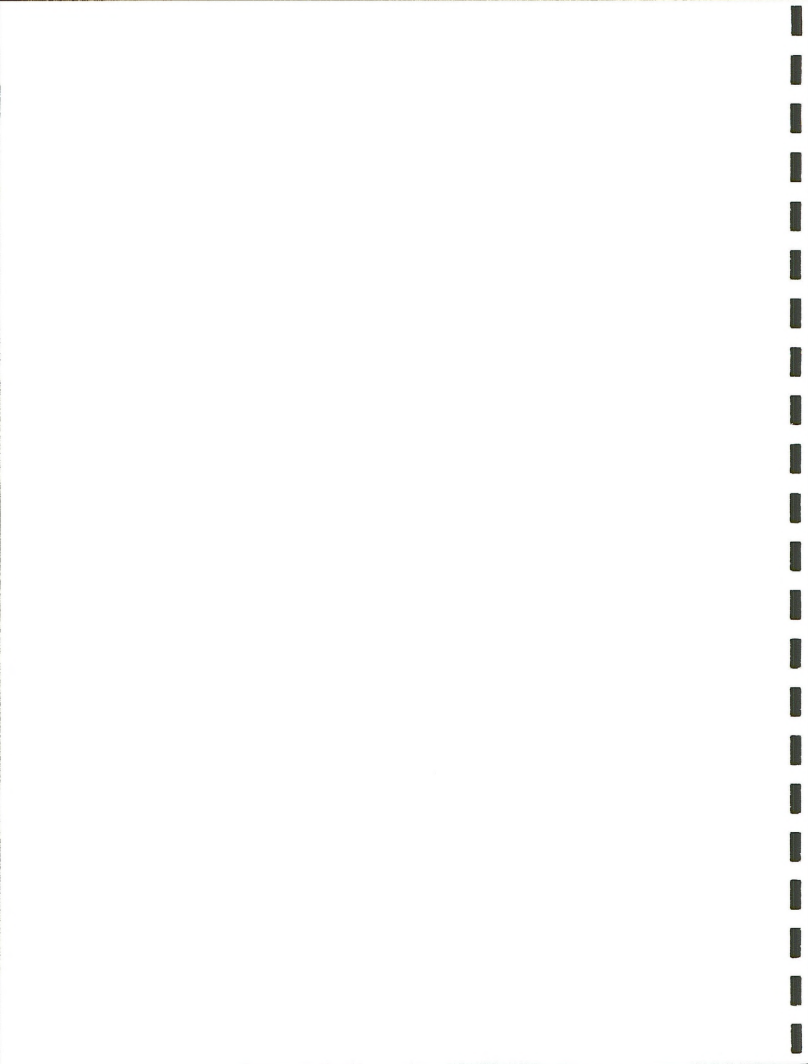
Table 11.   Analysis of Variance Results of Soil Samples.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Estimated Variance Component	Percent of Total Variance
Hg						
1.6 km	0.0865	3	0.0288	0.54	0	0
0.4-1.6 km	0.2127	4	0.0532	0.86	0	0
0.1-0.4 km	0.4949	8	0.0618	0.86	0	0
0-50 m	1.152	16	0.0719	3.39*	0.042	66.5
Replications	0.2121	10	0.0212		0.021	33.5
Zn						
1.6 km	0.0504	3	0.0168	1.82	0.0007	7.6
0.4-1.6 km	0.0369	4	0.0092	0.584	0	0
0.1-0.4 km	0.1263	8	0.0158	3.36*	0.0045	47.4
0-50 m	0.0719	16	0.0047	2.53	0.0024	25.3
Replications	0.0149	8	0.0019		0.0019	19.6
Li						
1.6 km	0.6232	3	0.2077	3.31	0.0130	29.0
0.4-1.6 km	0.2505	4	0.0626	0.82	0	0
0.1-0.4 km	0.6077	8	0.0759	16.85*	0.0278	62.2
0-50 m	0.0721	16	0.0045	2.73*	0.0023	5.1
Replications	0.0198	12	0.0016		0.0017	3.7
B						
1.6 km	0.0258	3	0.0086	0.36	0	0
0.4-1.6 km	0.0965	4	0.0241	0.36	0	0
0.1-0.4 km	0.5425	8	0.0678	7.86*	0.0221	75.2
0-50 m	0.1379	16	0.0086	4.96*	0.0056	18.9
Replications	0.0191	11	0.0017		0.0017	5.9
Mo						
1.6 km	0.4606	3	0.1535	12.7*	0.0148	18.6
0.4-1.6 km	0.0483	4	0.0121	0.09	0	0
0.1-0.4 km	1.016	8	0.1270	6.06*	0.0463	58.0
0-50 m	0.3351	16	0.0209	7.66*	0.0159	19.9
Replications	0.0164	6	0.0027		0.0027	3.4
As						
1.6 km	0.7521	3	0.2507	32.64*	0.0193	57.7
0.4-1.6 km	0.0307	4	0.0077	0.24	0	0
0.1-0.4 km	0.2534	8	0.0317	4.89*	0.0083	24.9
0-50 m	0.1035	16	0.0065	1.45	0.0014	4.0
Replications	0.0848	19	0.0045		0.0045	13.4
Organic Carbon						
1.6 km	1.469	3	0.4895	6.78*	0.0398	50.9
0.4-1.6 km	0.2886	4	0.0722	1.27	0.0024	3.1
0.1-0.4 km	0.4549	8	0.0569	1.67	0.0077	9.9
0-50 m	0.5454	16	0.0340	12.39*	0.0255	32.6
Replications	0.0275	10	0.0028		0.0028	3.5
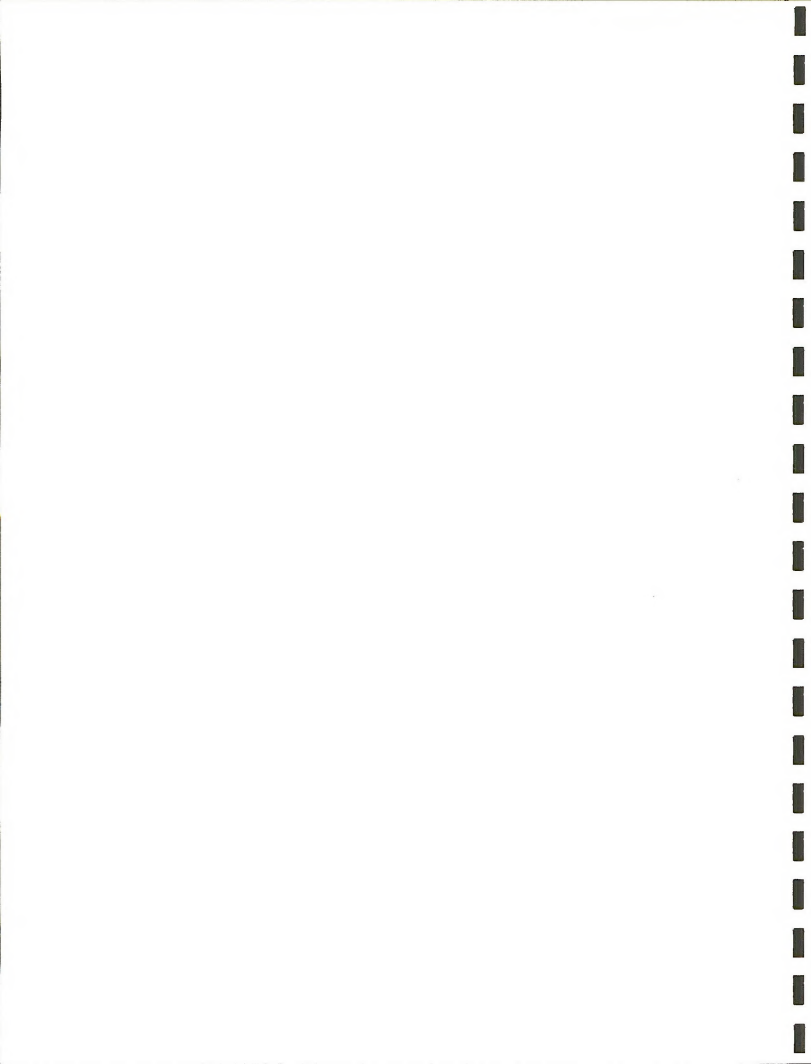
Table 11. (Continued)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Estimated Variance Component	Percent of Total Variance
pH						
1.6 km	0.0974	3	0.0329	0.13	0	0
0.4-1.6 km	1.048	4	0.2619	0.86	0	0
0.1-0.4 km	2.448	8	0.3059	2.98*	0.0621	46.6
0-50 m	1.644	16	0.1028	9.08*	0.0597	44.9
Replications	0.2267	20	0.0113		0.0113	8.5

Analytical Variability Determined from All Samples Analyzed.

Element	Percent Deviation
Hg	17.7
Zn	5.9
Li	3.1
B	5.1
Mo	8.6
Org C	5.8
pH	0.8
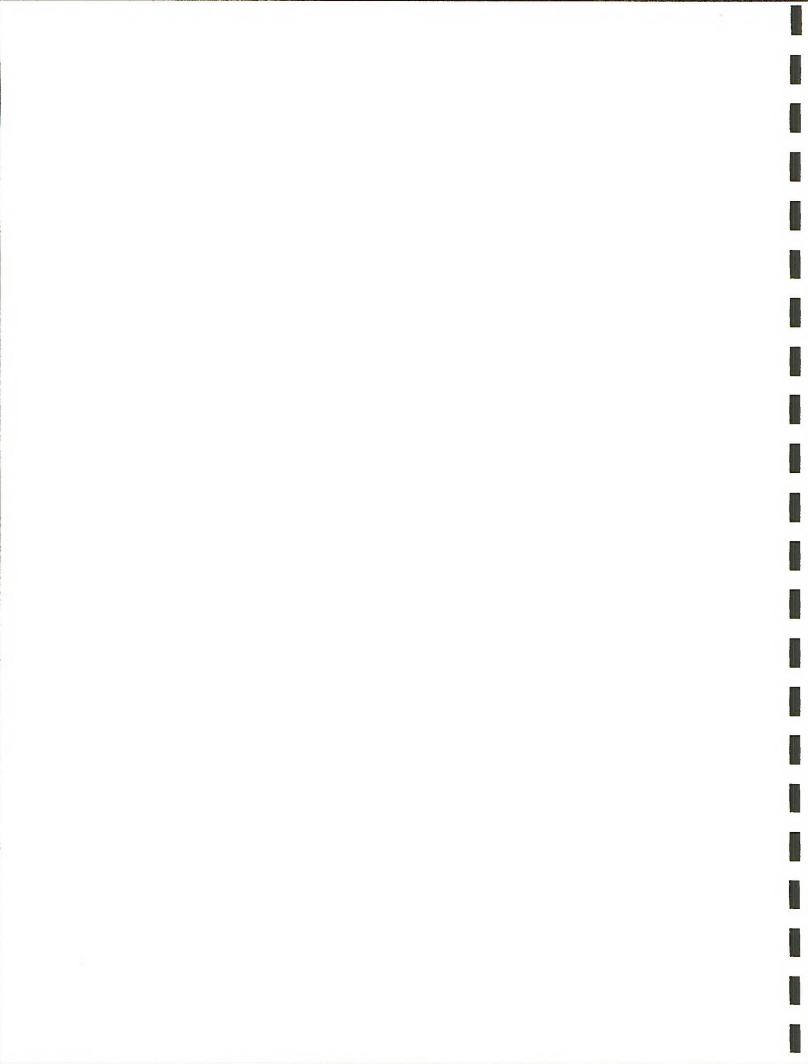
Table 12. Analysis of Variance Results from
           Sagebrush Samples.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Estimated Variance Component	Percent of Total Variance
Zn						
1.6 km	0.4306	3	0.1514	1.31	0.0037	2.1
0.4-1.6 km	0.4624	4	0.1156	1.67	0.0103	6.0
0.1-0.4 km	0.5527	8	0.0690	0.42	0	0
0-50 m	2.586	16	0.1616	1.23	0.0265	15.5
Replications	0.9182	7	0.1312		0.1312	76.4
B						
1.6 km	0.0861	3	0.0287	2.87	0.0022	31.6
0.4-1.6 km	0.0399	4	0.0099	2.06	0.0011	16.5
0.1-0.4 km	0.0387	8	0.0048	1.80	0.0010	14.9
0-50 m	0.0403	15	0.0097	11.07*	0.0023	33.5
Replications	0.0007	3	0.0002		0.0002	3.5
Mo						
1.6 km	0.4306	3	0.1435	3.82	0.0100	18.3
0.4-1.6 km	0.1504	4	0.0376	0.39	0	0
0.1-0.4 km	0.7698	8	0.0962	4.39*	0.0276	50.2
0-50 m	0.3283	15	0.0219	8.04*	0.0146	26.6
Replications	0.0354	13	0.0027		0.0027	4.9

*Significantly different from zero at α = .05

Analytical Variability Determined from All
Sage Samples Analyzed.

Element	Percent Deviation
Mo (sage)	4.9
B (sage)	2.0
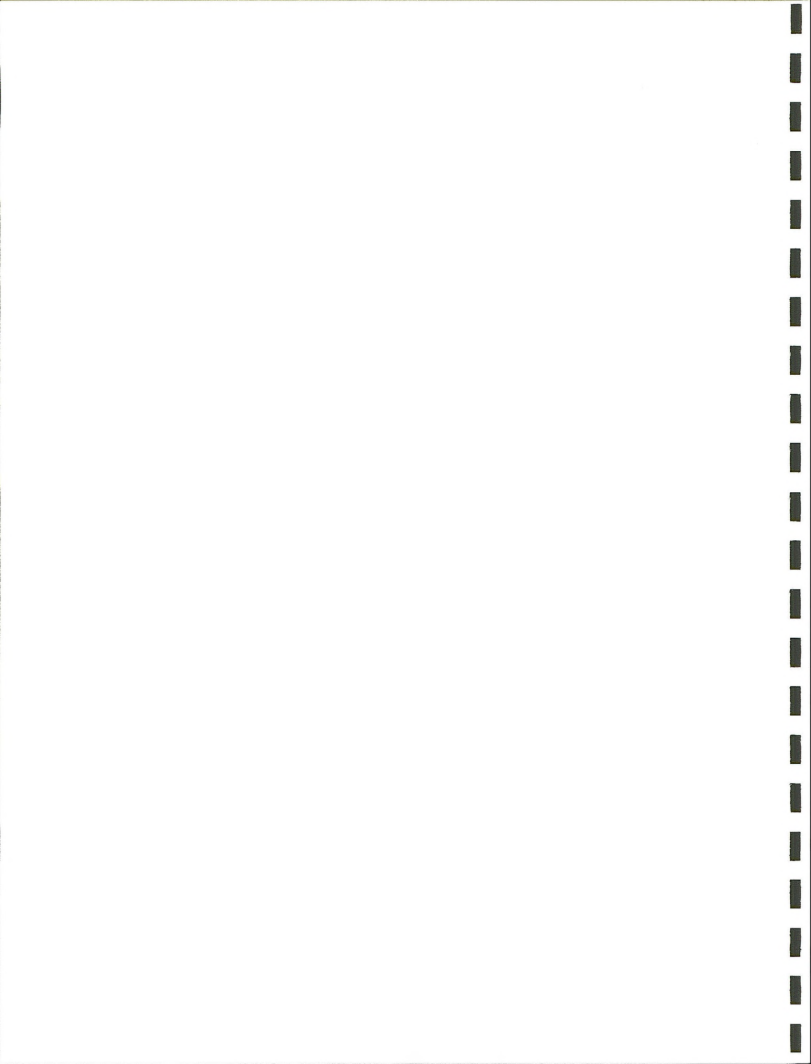
Table 13.   Analysis of Variance Results for
            Ricegrass Samples.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Estimated Variance Component	Percent of Total Variance
Hg						
1.6 km	0.1618	3	0.0539	1.44	0.0018	5.1
0.4-1.6 km	0.1502	4	0.0376	2.15	0.0049	13.8
0.1-0.4 km	0.1395	8	0.0174	0.56	0	0
0-50 m	0.4051	13	0.0312	4.65*	0.0222	62.3
Replications	0.0268	4	0.0067		0.0067	18.8
Zn						
1.6 km	0.1454	3	0.0485	0.64	0	0
0.4-1.6 km	0.3047	4	0.0762	0.88	0	0
0.1-0.4 km	0.6943	8	0.0868	0.33	0	0
0-50 m	3.386	13	0.2605	8.62*	0.2138	87.6
Replications	0.0906	3	0.0302		0.0302	12.4
B						
1.6 km	0.0829	3	0.0277	1.21	0.0004	2.1
0.4-1.6 km	0.0918	4	0.0229	0.83	0	0
0.1-0.4 km	0.2206	8	0.0276	2.54	0.0068	40.4
0-50 m	0.1735	16	0.0108	13.63*	0.0089	52.8
Replications	0.0056	7	0.0008		0.0008	4.7
Mo						
1.6 km	0.2832	3	0.0944	4.13	0.0070	20.2
0.4-1.6 km	0.0915	4	0.0229	0.48	0	0
0.1-0.4 km	0.3785	8	0.0473	2.39	0.0099	28.8
0-50 m	0.2972	15	0.0198	3.38*	0.0117	33.9
Replications	0.0587	10	0.0059		0.0059	16.9

Table 14. Analysis of Variance Results for
Wheatgrass Samples.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Estimated Variance Component	Percent of Total Variance
Hg						
1.6 km	0.1618	3	0.0539	1.44	0.0018	5.1
0.4-1.6 km	0.1502	4	0.0376	2.15	0.0049	13.8
0.1-0.4 km	0.1395	8	0.0174	0.55	0	0
0-50 m	0.4051	13	0.0316	4.65*	0.0222	62.3
Replications	0.0268	4	0.0067		0.0067	18.8
Zn						
1.6 km	0.0206	2	0.0103	0.90	0	0
0.4-1.6 km	0.0343	3	0.0142	0.69	0	0
0.1-0.4 km	0.0981	6	0.0163	0.61	0	0
0-50 m	0.2945	11	0.0268	1.56	0.0088	33.8
Replications	0.0859	5	0.0172		0.0172	66.2
B						
1.6 km	0.0126	2	0.0063	0.94	0	0
0.4-1.6 km	0.0201	3	0.0067	0.21	0	0
0.1-0.4 km	0.1872	6	0.0312	1.27	0.0023	9.8
0-50 m	0.2443	10	0.0244	22.42*	0.0203	85.6
Replications	0.0054	5	0.0011		0.0011	4.6
Mo						
1.6 km	0.0484	2	0.0242	0.51	0	0
0.4-1.6 km	0.1416	3	0.0473	0.80	0	0
0.1-0.4 km	0.3529	6	0.0588	6.22*	0.0230	70.4
0-50 m	0.0946	10	0.0095	0.98	0	0
Replications	0.0483	5	0.0097		0.0096	29.6
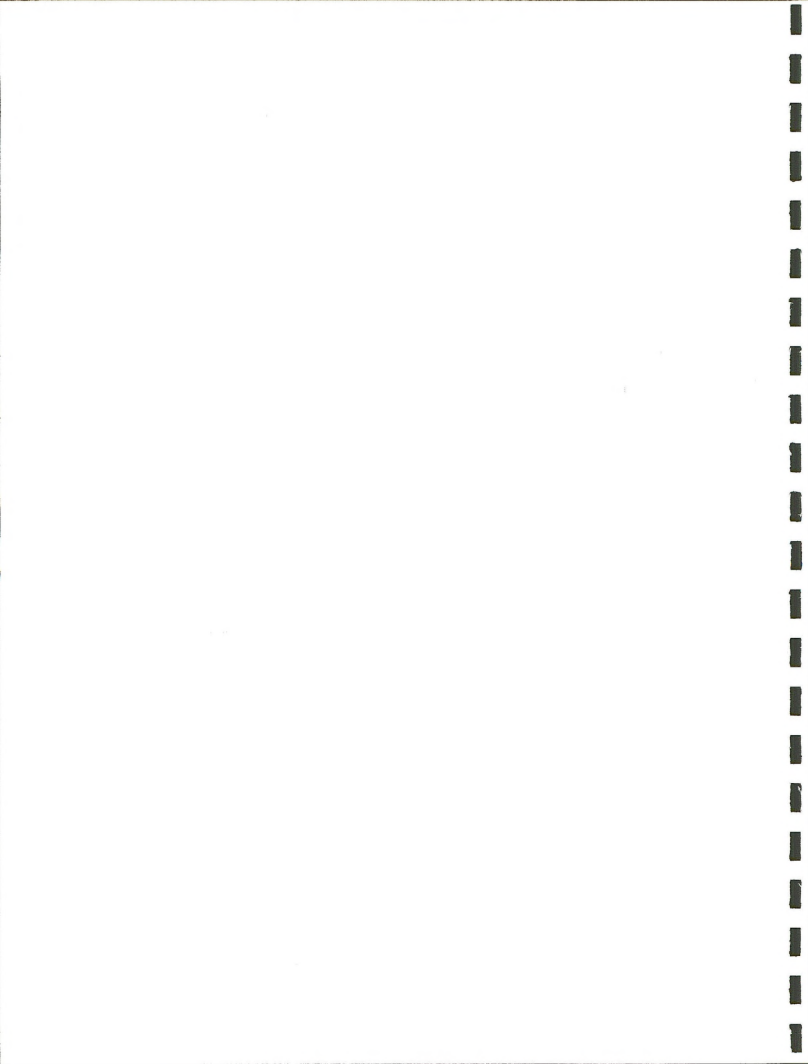
APPENDIX III

Computer Programs

The program Nest (Table 15) was used to examine the analysis of variance samples. Figure 22 shows the hierarchial model with three input parameters (NL's) that describe the nested sampling model used in this study.

The programs used to find geometric means and deviations (Table 18) and analytical variability (Table 16) were adapted from Klusman (1976).

Data Files

Table 19 lists the analysis of variance data and the plot is shown in Figure 6. Table 21 lists the grid data and Figure 5 shows the plot of this data. The flags used in both data sets are on the line proceeding the data for each point. A zero indicates the sample was collected on the Uinta Formation. A 90 shows the sample was taken on the Parachute Creek member. A 08 shows that the sage sample was subspecies wyomingensis.

Figures 18 to 21 show the data used in hypothesis tests (Groups 1-4).
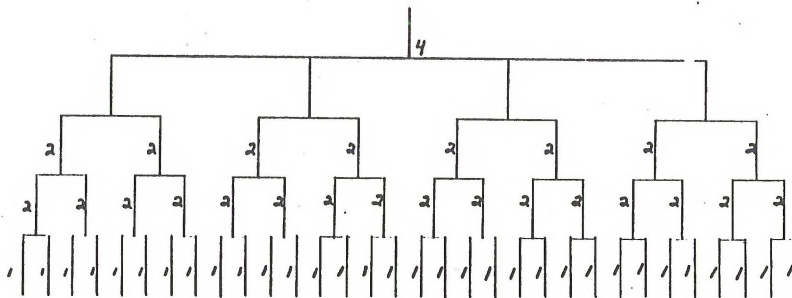
Figure 22. Analysis of Variance
Model Showing Values of NL used
in the Computer Program Nest.
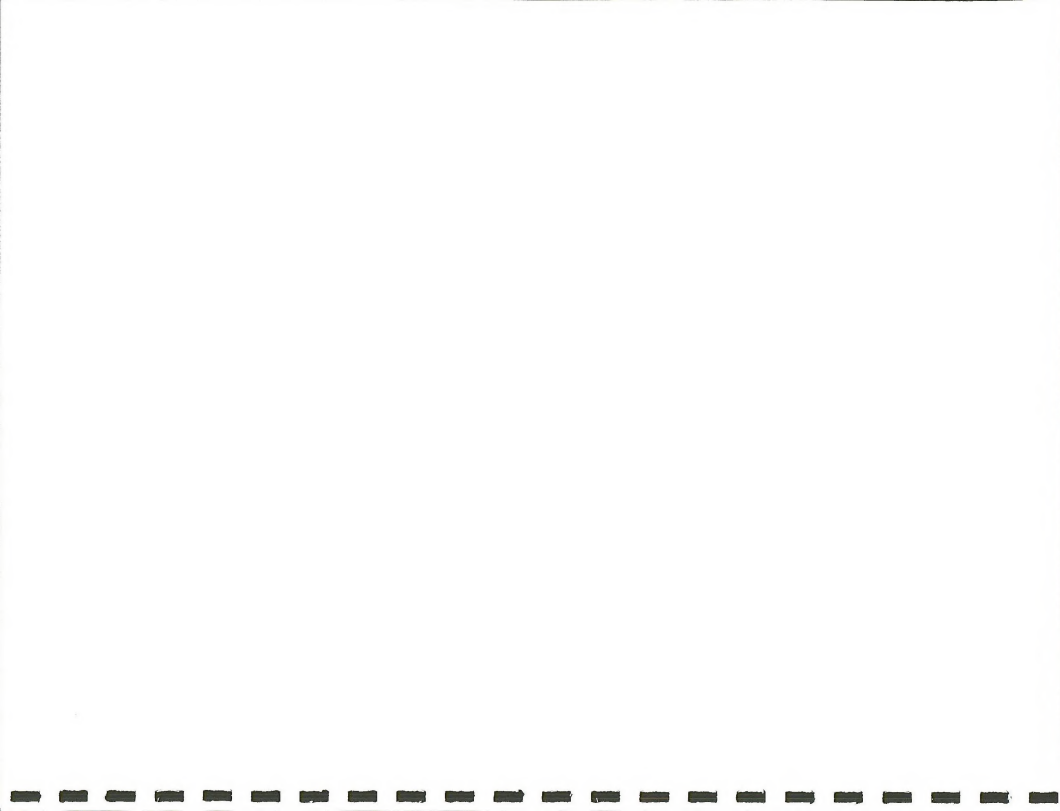
```
C    PROGRAM TO PERFORM ANALYSIS OF VARIANCE ON NESTED SAMPLING MODELS
C    TO EXECUTE PROGRAM TYPE IN :  " EX NEST.11,LBY;IMSL/SEARCH  " AFTER
     FILE HAS BEEN OBTAINED IN YOUR AREA.
         DIMENSION NL(999),Y(999),S(999),NDF(999),EMS(999),IWK(9
   1 99)
         DIMENSION NS(999),YY(999),YS(999)
         DIMENSION AREA(999),SIG(999),PCSIG(999)
         DIMENSION WMSG(999),FVAL(999)
         DOUBLE PRECISION A,B,C
   4     WRITE(4,5)
   5     FORMAT(1X,'ENTER INPUT FILE NAME FOR NLS: -----.DAT')
         READ (4,6) A
   6     FORMAT(1A10)
         WRITE(4,7)
   7     FORMAT(1X,'ENTER INPUT FILE NAME FOR DATA VALUES:-----.DAT')
         READ(4,6) B
         WRITE(4,8)
   8     FORMAT(1X,'ENTER OUTPUT FILE NAME : -----.DAT')
         READ(4,6) C
         OPEN(UNIT=8,FILE=C)
         OPEN(UNIT=10,FILE =A)
         OPEN(UNIT=12,FILE=B)
         IFLAG=0
         NCT=1
           NYCT=0
         IF (IFLAG.EQ.0)GO TO 50
         IF(IFLAG.EQ.0) GO TO 4
  12     NCT=1
C    READ IN INPUT VECTOR (NL)CONTAINING THE NUMBER OF LEVELS OF
C    EACH FACTOR AT ALL THE NESTED LEVELS OF EACH FACTOR SEE DOC-
C    UMENTATION FOR EXAMPLE, USE A FLAG OF 99 AT THE END OF EACH
C    NL SET, A FLAG OF 92 AT THE END OF THE LAST NL SET, IF NO
C    MERGING OF THE NL SUBSETS IS DESIRED A FLAG OF 90 IS SUFFICIENT,
C    NL'S ARE ENTERED 20 PER LINE SEPARATED BY " , " BEGIN A NEW
C    LINE AFTER A 90 OR 99 FLAG HAS BEEN ENTERED.
  20     READ(12,32)(NL(I),I=1,20)
  32     FORMAT(22I)
         DO 40 I=1,20
         IF (NL(I).EQ.90) GO TO 460
         NS(NCT)=NL(I)
         NCT=NCT+1
  40     CONTINUE
         GO TO 20
C    TYPE IN THE VALUE OF NF: NUMBER OF FACTORS IN THE MODEL
  50     WRITE(4,60)
  60     FORMAT(1H0,'ENTER THE VALUE FOR NF'/)
         READ(4,70) NF
  70     FORMAT(I1)
         NF1=NF+1
         NF2=NF*(NF+1)/2
         NCT=1
C    READ IN THE FIRST SET OF NL'S
  80     READ(10,90)(NL(I),I=1,20)
  90     FORMAT(20I)
         DO 122 I=1,20
         IF(NL(I).NE.90) GO TO 100
         IFLAG=1
         GO TO 125
  100    IF(NL(I).NE.99) GO TO 110
         GO TO 125
```

```
113       NS(NCT)= NL(I)
          NCT=NCT+1
120       CONTINUE
          GO TO 82
C     READ IN THE DATA(Y), (ONE PIECE PER LINE)
C     USE A FLAG OF 99 AT THE END OF THE SET
C     CONVERSION OF DATA TO LOG(10) VALUES IF DESIRED
125       WRITE(4,126)
126       FORMAT(1X,'IF LOG CONVERSION OF DATA IS DESIRED TYPE 2, IF NOT,
         1 TYPE 1'/)
          READ(4,77) ILOG
130       J=1
140       READ(12,150) YY(J)
          IF(YY(J).EQ.99.) GO TO 180
          IF(ILOG.EQ.1) GO TO 145
          Y(J) = ALOG10 (YY(J))
          GO TO 160
145       Y(J)=(YY(J))
150       FORMAT(F10.3)
160       NYCT=NYCT+1
          YS(NYCT)= Y(J)
          J=J+1
          GO TO 140
C     WRITE OUT DATA VALUES TO TTY AND FILE
180       WRITE (8,185)
185       FORMAT(1X,//,10X,'DATA AND NL VALUES',//)
          WRITE(8,482)(Y(J),J=1,NYCT)
          WRITE(8,230)(NS(I),I=1,NCT)
          WRITE(4,190)(NS(I),I=1,NCT)
190       FORMAT(/,2012/)
220       FORMAT(/4012/)
C     CALL ANESTU SUBROUTINE TO ANALYSE NESTED DATA
          CALL ANESTU(NF,NS,Y,GM,S,NDF,EMS,IWK,IER)
C     CALCULATE MEAN SQUARE VALUES
          DO210 I=1,NF
          WMSQ(I)= S(I) / FLOAT(NDF(I))
210       CONTINUE
C     CALCULATE F STAT. VALUES
          DO 220 I=1,NF-1
          FVAL(I) = WMSQ(I) / WMSQ(I+1)
220       CONTINUE
          WRITE(4,230)
          WRITE(8,230)
230       FORMAT(1X,//'EXPECTED MEAN SQUARE COEFICIENTS'//)
240       FORMAT(F10.5,I10)
          IS=1
          IF=NF
C     WRITE OUT EXPECTED MEAN SQUARE COEFFICIENTS
          DO 250 N=1,NF
          WRITE(4,260)(EMS(I),I=IS,IF)
          WRITE(8,260)(EMS(I),I=IS,IF)
          IS=IF+1
          IF=IS+(NF-N)-1
250       CONTINUE
260       FORMAT(12F10.4)
          WRITE(4,270)
C     CONFIRM VALIDITY OF DATA, IF BAD PRGM, STARTS OVER.
270       FORMAT(1X,'IF DATA IS GOOD,ENTER1, IF BAD,ENTER 3')
          READ(4,290) IPRINT
280       FORMAT(I4)
```
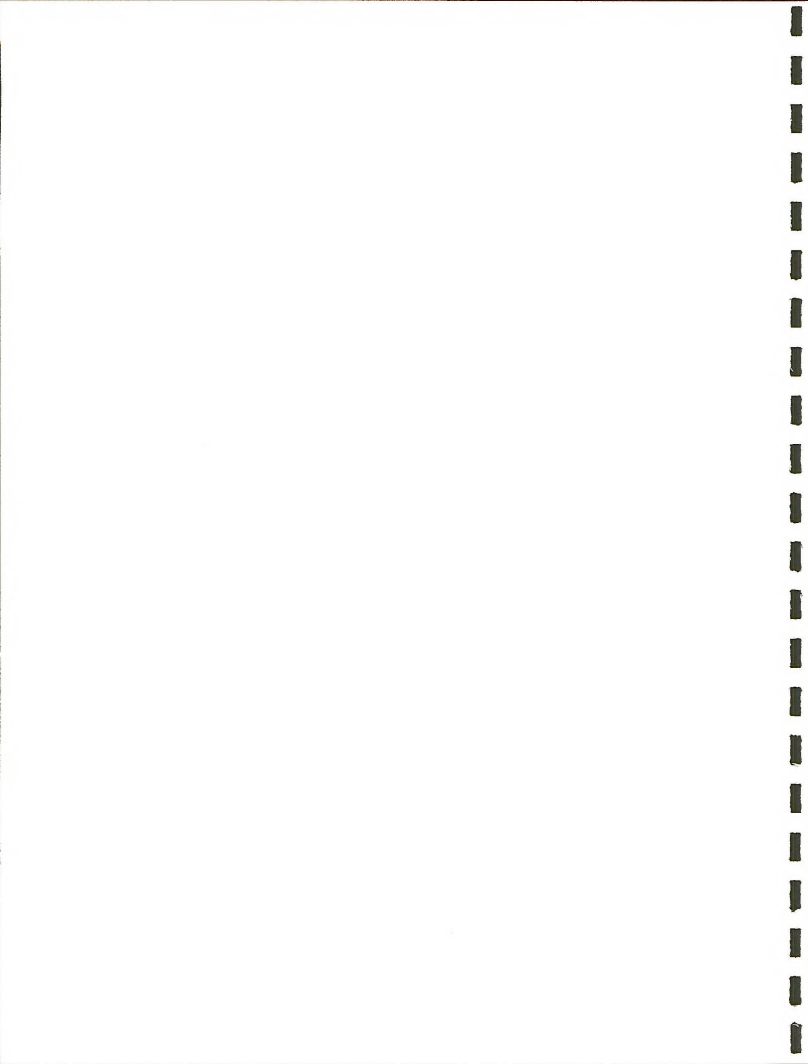
```
          IF(IPRINT.EQ.1) GO TO 290
          GO TO 10
290       WRITE(4,300)
C     TYPE IN AND WRITE OUT AREA TITLE
300       FORMAT(1X,'ENTER AREA TITLE,UP TO 24 SPACES'/)
          READ(4,310)(AREA(L),L=1,4)
310       FORMAT(4A5)
          WRITE (8,320)(AREA(L),L=1,4)
320       FORMAT(1H0,(4A5)/)
330       FORMAT(1X,//,3X,'TOTAL SUM OF SQUARES',5X,'DEG. OF FREEDOM'/)
C     CALCULATE ESTIMATED COMPONENTS OF VARIANCE
340       SIG(NF)=S(NF)/NDF(NF)
          SIG(NF-1)=(S(NF-1)/NDF(NF-1) - SIG(NF))/EMS(NF2-1)
          IF ((NF-2).EQ.0) GO TO 360
          SIG(NF-2)=(S(NF-2)/NDF(NF-2)-SIG(NF)-EMS(NF2-4)*SIG(NF-1
     1    ))/EMS(NF2-3)
          IF((NF-3).EQ.0)GO TO 360
          SIG(NF-3)=(S(NF-3)/ NDF(NF-3)-SIG(NF)-EMS(NF2-8)* SIG(NF
     1    -1)-EMS(NF2-7)*SIG(NF-2))/ EMS(NF2-6)
          IF((NF-4).EQ.0) GO TO 360
          SIG(NF-4)=(S(NF-4)/NDF(NF-4)-SIG(NF)-EMS(NF2-13)*EMS(NF-
     1    1)-EMS(NF2-12)*SIG(NF-2)-EMS(NF2-11)*SIG(NF-3))/EMS(NF2-
     1    10)
          IF((NF-5).EQ.0) GO TO 360
          SIG(NF-5)=(S(NF-5)/NDF(NF-5)-SIG(NF)-EMS(NF2-19)*SIG(NF-
     1    -1)-EMS(NF2-18)*SIG(NF-2)-EMS(NF2-17)*SIG(NF-3
     1    )-EMS(NF2-16)*SIG(NF-4)/ EMS(NF2-15)
350       FORMAT(1X,F15.6,2X,I10,F10.6 ,5X,F10,6  //)
C     WRITE OUT COLUMN HEADINGS FOR ANOVA TABLE
360       WRITE(8,370)
          WRITE(4,370)
370       FORMAT(1X,'LEVEL',10X,'SUM OF SQUARES',10X,'DEG. CF FR,',
     1    17X,'MEAN SQUARE',10X,'F VALUE',8X,'EST. COMP. OF VAR.',
     1    6X,'PCT.OF TOT VAR,'////)
C     CALCULATE TOTAL ESTIMATED COMP. OF VARIANCE(TOTSIG) OMMITING
C     VALUES LESS THAN OR EQUAL TO ZERO
          DO380 I=1,NF
          IF((SIG(I)).LE. 0.) GO TO 380
          TOTSIG= TOTSIG+SIG(I)
380       CONTINUE
C     CALCULATE PERCENT OF TOTAL VARIANCE (PCSIG)
          DO390 I=1,NF
          PCSIG(I)= (SIG(I) / TOTSIG ) *(100)
          IF((SIG(I)) .LE. 0.) PCSIG(I)=0.
390       CONTINUE
400       FORMAT(F10.5)
C     WRITE OUT ANOVA TABLE
          DO420 I=1,NF
          WRITE(8,410)I,S(I),NDF(I),WMSQ(I),FVAL(I),SIG(I),PCSIG
     1    (I)
          WRITE(4,410)I,S(I),NDF(I),WMSQ(I),FVAL(I),SIG(I),PCSIG
     1    (I)
410       FORMAT(1X,3X,I3,11X,F10.6,13X,I3,13X,F10.6,8X,F13.4,12X
     1    ,F10.5,10X,F10.4,///)
420       CONTINUE
          WRITE(4,330)
          WRITE(8,330)
          WRITE(4,440)S(F1),NDF(NF1)
C     WRITE TOTAL SUM OF SQUARES AND DEGREES OF FREEDOM
```
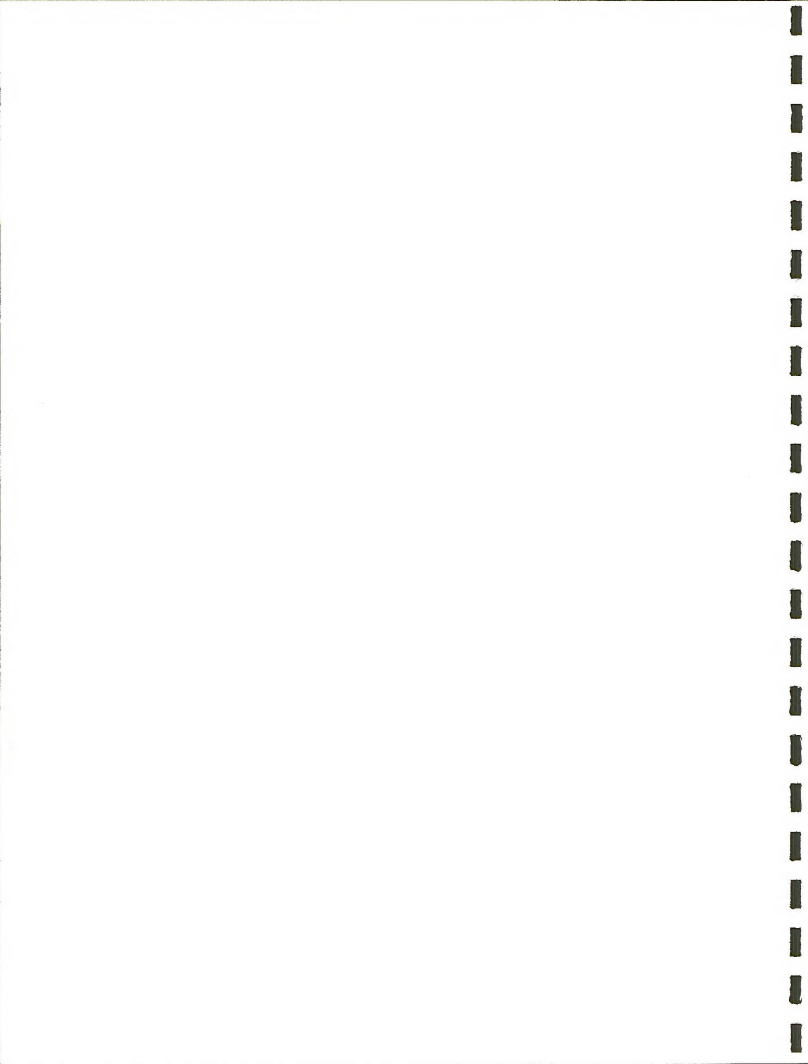
```
      WRITE(8,442)S(NF1),NDF(NF1)
C     WRITE GRAND MEAN AND ERROR PARAMETER
      WRITE(4,432)
      WRITE(8,432)
43?   FORMAT(1X,//,2X,'GRAND MEAN',10X,'ERROR PARAMETER'/)
      WRITE(8,443) GM,IER
      WRITE(4,443)GM,IER
442   FORMAT(F12.3,13X,I17)
C     ENTER 0 IF MORE DATA, 1 TO MERGE DATA SETS, 2 TO STOP
      WRITE(4,453)
453   FORMAT(1X,'IF MORE DATA,ENTER 0,IF MERGE ENTER 1, IF STO
     1P , ENTER 2')
      READ(4,280) IFLAG
      IF(IFLAG.EQ.2) CALL EXIT
      GO TO 13
C     ANALYSE MERGED DATA SETS
C     NOTE A NEW SET OF NL'S MUST BE ENTERED CONSTRUCTED FROM
C     THE NEWLY COMBINED OR MERGED VALUES
463   WRITE(4,63)
      READ(4,77) NF
473   FORMAT((10I))
      WRITE(8,472) (NS(I),I=1,NCT)
      WRITE(8,482) (YS(I),I=1,NYCT)
483   FORMAT(8F13.4)
      NF1=NF+1
      NF2=NF*(NF+1)/2
      CALL ANESTU(NF,NS,YS,GM,S,NDF,EMS,IWK,IER)
C     ENTER ELEMENT NAME
      WRITE(4,493)
493   FORMAT(1X,'ENTER ELEMENT'/)
      READ(4,523) ELEM
523   FORMAT(A6)
      WRITE(8,512)ELEM
513   FORMAT(1X,A6)
      WRITE(4,242)(S(I),NDF(I),I=1,NF1)
      WRITE(4,263)(EMS(I),I=1,NF2)
      WRITE(8,242)(S(I),NDF(I),I=1,NF1)
      WRITE(8,263)(EMS(I),I=1,NF2)
      WRITE(8,443) GM,IER
      IFLAG=2
      GO TO 347
      STOP
      END
```
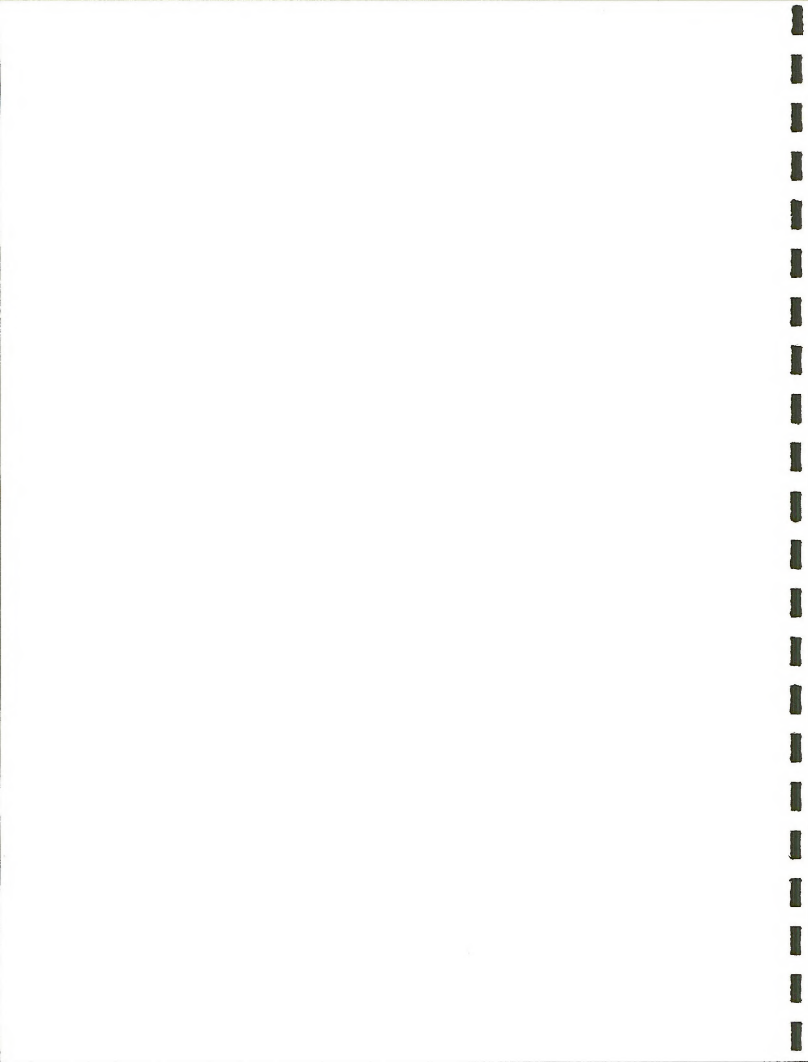
```
C PROGRAM TO DETERMINE ANALYTICAL VARIABILITY OF REPLICANTS
C DATA IS READ FROM FOR08.DAT , FORMAT MUST BE ENTERED FOR EACH ELEMENT
C IN STATEMENT # 123. THIS VERSION WILL ACCOMODATE DATA WHERE SOME OR
C ALL SAMPLES ARE REANALYZED; ALSO IF SOME ELEMENTS ARE NOT DETERMINED
C FOR ALL SAMPLES.
      DIMENSION DATA(12)
    6 READ(19,127) LABEL
  120 FORMAT(A4)
      IF(LABEL.EQ.4H9999) GO TO 1
      GSUM1=3.
      GSUM2=3.
      GSUM3=2.
      K=2
      WRITE(6,131) LABEL
  101 FORMAT(1H1,33X,A4)
      WRITE(6,102)
  102 FORMAT(1H2,4HDATA/56H ARITHMETIC    STANDARD    PERCENT   GEOMETRIC
     1 GEOMETRIC/54H           MEAN    DEVIATION DEVIATION    MEAN    DEVIAT
     2ION)
    7       CONTINUE
        DO 11 I=1,3
        READ(8,103)DATA(I)
  103 FORMAT(54X,F5.1)
   11       CONTINUE
      N=1
      SUM=0.
      SUM2=0.
      SUML=0.
      SUML2=0.
C IF THE FIRST VALUE OF DATA(I) = 0.0 READ THE NEXT VALUE SINCE THIS
C ELEMENT WAS NOT DETERMINED FOR THIS SAMPLE
      IF(DATA(1).EQ.0.)GO TO 7
    4 IF(DATA(N).EQ.0.) GO TO 2
      IF(DATA(N).EQ. 9.9) GO TO 3
      IF(DATA(N).LT.0.00) DATA(N)=ABS(DATA(N))
      SUM=SUM+DATA(N)
      SUML=SUML+ALOG10(DATA(N))
      SUM2=SUM2+(DATA(N))**2
      SUML2=SUML2+(ALOG10(DATA(N)))**2
      N=N+1
      GO TO 4
    2 N=N-1
      WRITE(7,124)(DATA(I),I=1,N)
  104 FORMAT(1H ,13F6.2)
      XN=FLOAT(N)
      XMEAN=SUM/XN
      GMEAN=EXP(2.303*(SUML/XN))
      IF(N.EQ.1)GO TO 99
      XDEV=SQRT((1./((XN**2)-XN))*(((XN*SUM2)-(SUM**2))))
      GDEV=EXP(2.303*(SQRT((1./((XN**2)-XN))*(((XN*SUML2)-(SUML**2))))))
      GO TO 85
   99 XDEV=2
      GDEV=0
   85     SPERD=0.
      DO 5 I=1,N
    5 SPERD=SPERD+ABS(((DATA(I)-XMEAN)/XMEAN)*100.)
      PERD=SPERD/XN
      WRITE(6,105) XMEAN,XDEV,PERD,GMEAN,GDEV
  125 FORMAT(1H ,5F10.3)
C IF DATA(2)=0.0 IT IS ASSUMED THAT THIS SAMPLE WAS NOT RE----
```
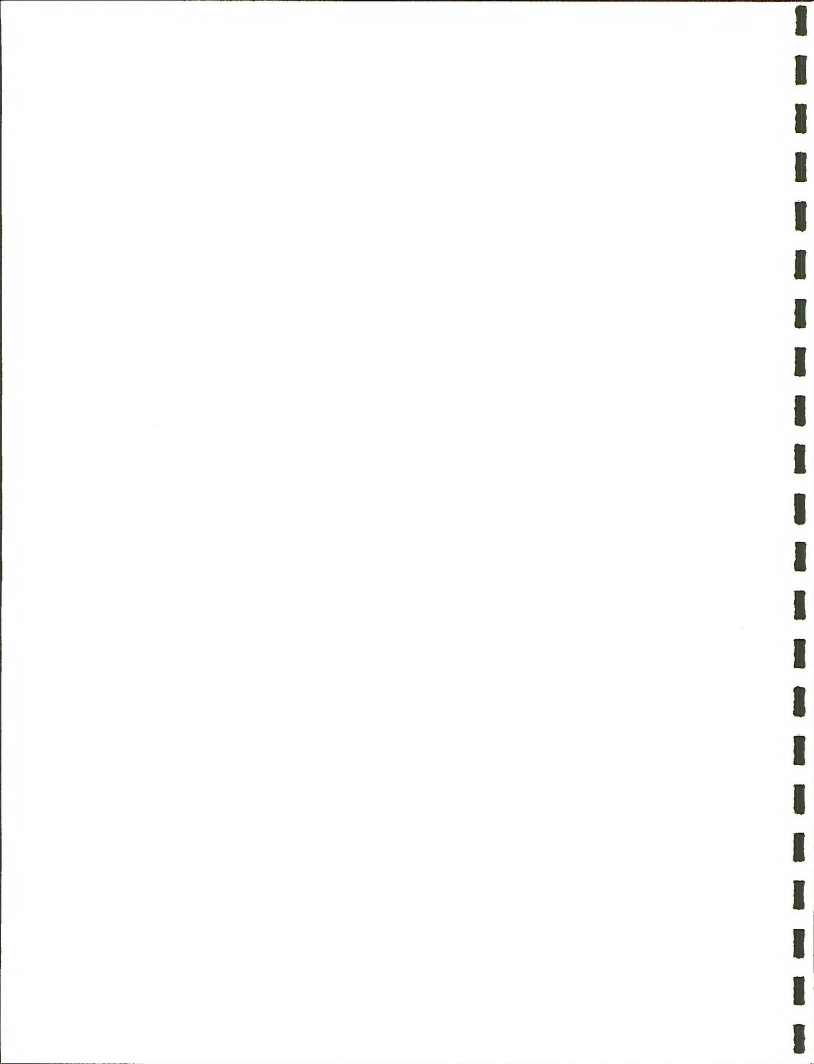
```
C ANALYZED AND THE NEXT SAMPLE SHOULD BE READ SO THE COUNTER WILL NOT
C BE ALTERED AND THE CORRECT AVG. DEVIATIONS CAN BE COMPUTED.
      IF(DATA(2).EQ.0.)GO TO 7
      GSUM1=GSUM1+XDEV
      GSUM2=GSUM2+PERD
      GSUM3=GSUM3+GDEV
      K=K+1
      GO TO 7
    3 XK=FLOAT(K)
      AVDEV=GSUM1/XK
      WRITE(6,106) LABEL,AVDEV
  106 FORMAT(1H0,31HAVERAGE STANDARD DEVIATION FOR ,A4,3H = ,F10.3)
      AVPER=GSUM2/XK
      WRITE(6,107) LABEL,AVPER
  107 FORMAT(1H ,30HAVERAGE PERCENT DEVIATION FOR ,A4,3H = ,F10.3)
      AGDEV=GSUM3/XK
      WRITE(6,108) LABEL,AGDEV
  108 FORMAT(1H ,32HAVERAGE GEOMETRIC DEVIATION FOR ,A4,3H = ,F10.3)
      GO TO 6
    1 END
```
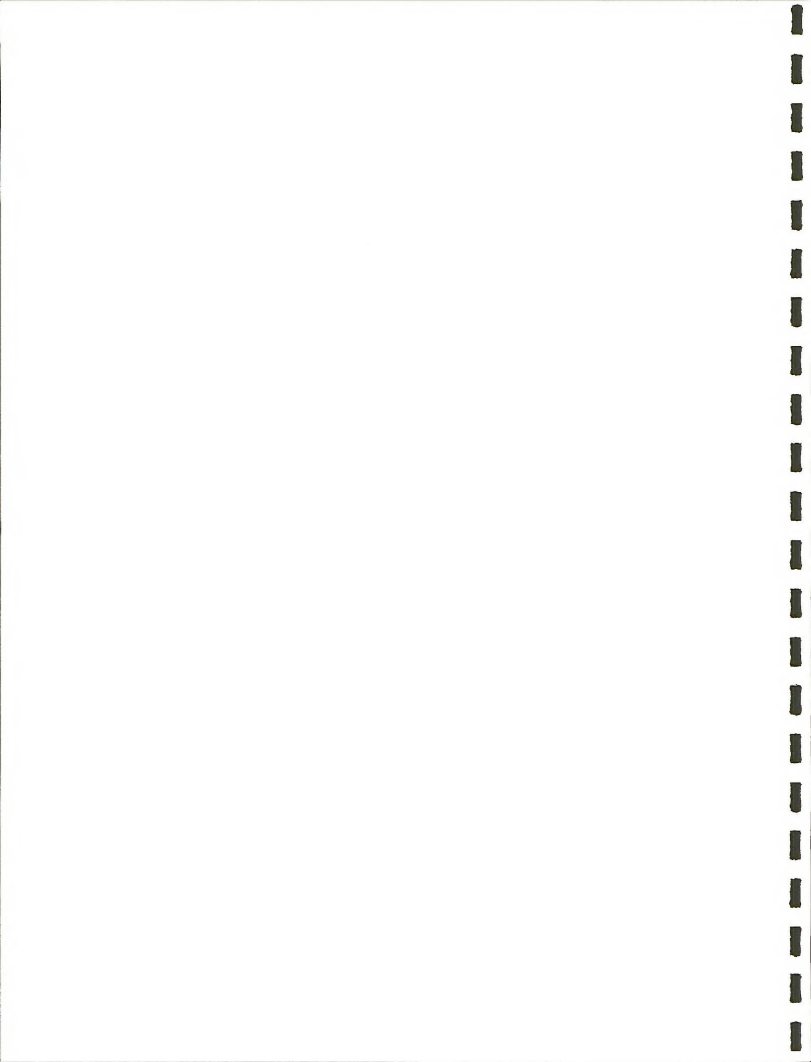
```
       DIMENSION LABEL(12),IFMT(16),IHEAD(16),JHEAD(16),DATA1(999,12),
      1DATA2(999,12),IOPT(12),XDAT1(999),XDAT2(999),ICREEK(300) ,ISAMP1(
      1 300),ISAMP2(300)
C READ IN NUMBER OF DATA BATCHES, NUMBER OF ELEMENTS
C ABATCH IS DEFINED AS 2 SETS OF DATA FOR WHICH THE T-TEST FOR
C DIFFERENCE IN MEANS IS BEING RUN
       READ(13,127) MM,MMM
  107 FORMAT(2I2)
C READ IN ELEMENTS DETERMINED
       READ(13,101)(LABEL(I),I=1,12)
  101 FORMAT(12A4)
C READ IN LOG OR NORMAL OPTION FOR EACH ELEMENT
       READ(13,108)(IOPT(I),I=1,12)
  108 FORMAT(12A3)
C READ IN FLAG FOR END OF DATA SET
       READ(13,1221) FLAG
 1221    FORMAT(12F3.2)
C BEGIN LOOP THROUGH EACH BATCH OF DATA
       DO 1 M=1,MM
C READ IN HEADING FOR EACH DATA SET
       READ(13,103)(IHEAD(I),I=1,16)
       READ(13,123)(JHEAD(I),I=1,16)
   31    FORMAT(I3,17X,F4.2,1X,F3.2,1X,F3.0,1X,F4.2,1X,F4.1,1X,F4.2,1X,
      1 F5.2,1X,F5.1,2X,F4.2/)
 9999    FORMAT(1X,I3,9(3X,F6.2))
   36    FORMAT(I3,17X,F4.0,1X,F3.2,1X,F3.0,1X,F4.2,1X,F4.1,1X,F4.2,
      1 1X,F5.0,1X,F5.1,2X,F4.2/)
       N1=1
       N2=1
   32    FORMAT(I2)
    3    READ(8,32)ICREEK(I)
       IF(ICREEK(I).EQ.98) GO TO 3
       IF(ICREEK(I).EQ.9) GO TO 993
       IF(ICREEK(I).EQ.8) GO TO 3
       READ(8,31) ISAMP1(N1),(DATA1(N1,K),K=1,MMM)
       WRITE(4,9999)ISAMP1(N1),(DATA1(N1,K),K=1,MMM)
       IF(DATA1(N1,1).EQ.FLAG) GO TO 2
       N1=N1+1
       GO TO 3
    2    N1=N1-1
       GO TO 199
  993    READ(8,36)ISAMP2(N2),(DATA2(N2,K),K=1,MMM)
       IF(DATA2(N2,1).EQ.FLAG)GO TO 4
       N2=N2+1
       GO TO 3
    4    N2=N2-1
       GO TO 199
C WRITE FIRST HEADING
  199    WRITE(6,125)(IHEAD(I),I=1,16)
  125 FORMAT(1H1,16A5)
       WRITE(6,106)(LABEL(I),I=1,12)
  106 FORMAT(1H ,8X,A2,4(4X,A4))
  123 FORMAT(16A5)
       DO 112 I=1,N1
       WRITE(6,9999)ISAMP1(I),(DATA1(I,K),K=1,MMM)
  112    CONTINUE
C WRITE SECOND HEADING
       WRITE(6,137)(JHEAD(I),I=1,16)
  1 7    FORMAT(1X,16A5)
```
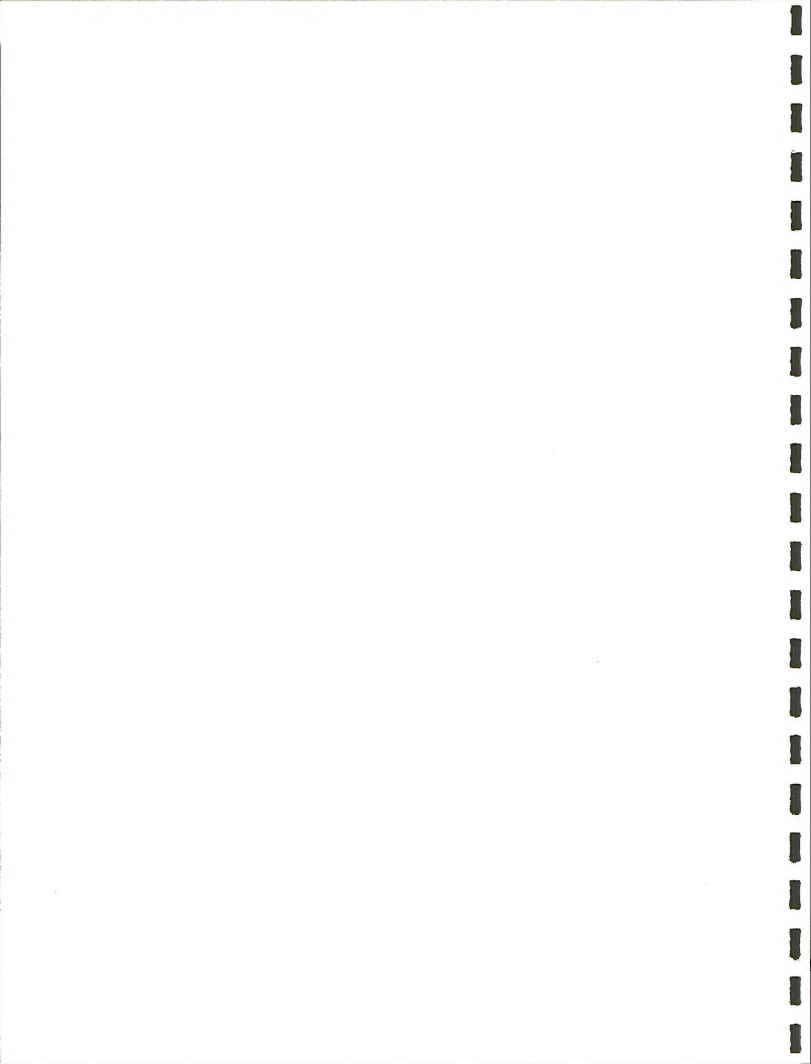
```
         DO 113 I=1,N2
         WRITE(6,9999)ISAMP2(I),(DATA2(I,K),K=1,MMM)
113      CONTINUE
C BEGIN LOOP THROUGH EACH ELEMENT
         DO 6 J=1,MMM
C SET COUNTERS TO ZERO
         J1=1
C MOVE ELEMENT BEING PROCESSED FROM MAIN ARRAYS TO WORKING ARRAYS,
C ELIMINATING BLANKS AND LESS THAN VALUES
         DO 7 N=1,N1
         IF(DATA1(N,J).LE.0.0) GO TO 7
         XDAT1(J1)=DATA1(N,J)
         J1=J1+1
    7    CONTINUE
         J1=J1-1
         J2=1
         DO 8 N=1,N2
         IF(DATA2(N,J).LE.0.0) GO TO 8
         XDAT2(J2)=DATA2(N,J)
         J2=J2+1
    8    CONTINUE
         J2=J2-1
C CHECK TO SEE WHICH WORKING ARRAY IS SMALLEST
         XCHG=0.0
         IF(J1.LE.J2) GO TO 9
C IF  DAT2 IS SMALLEST, INTERCHANGE DATA FOR COMPUTATIONAL CONVENIENCE
C LATER
         DO 10 N=1,J1
         TEMP=XDAT2(N)
         XDAT2(N)=XDAT1(N)
         XDAT1(N)=TEMP
   10    CONTINUE
         TEMP=J2
         J2=J1
         J1=TEMP
         XCHG=XCHG+1.0
C CHECK TO BE SURE SMALLEST ARRAY HAS AT LEAST 2 VALUES OR COMPUTATION
C WILL BLOW UP
         IF(J1.GT.1) GO TO 9
         WRITE(6,112) LABEL(J)
  112    FORMAT(1H0,22HINSUFFICIENT DATA FOR ,A4,13H TO COMPUTE T)
         GO TO 6
C CHECK LOG OPTION AND CONVERT TO LOGS IF NECESSARY
    9    IF(IOPT(J).NE.3HLOG) GO TO 11
         DO 12 N=1,J1
   12    XDAT1(N)=ALOG10(XDAT1(N))
         DO 13 N=1,J2
   13    XDAT2(N)=ALOG10(XDAT2(N))
C SET SUMS TO ZERO
   11    SUMU=0.0
         SUMU2=0.0
         SUMX1=0.0
         SUMX2=0.0
         XJ1=FLOAT(J1)
         XJ2=FLOAT(J2)
         ROOT=SQRT(XJ1/XJ2)
C COMPUTE SUMS OF THE DATA AND SUM U
         DO 14 N=1,J1
         SUMU=SUMU+XDAT1(N)-(XDAT2(N)*ROOT)
         SUMU2=SUMU2+((XDAT1(N)-(XDAT2(N)*ROOT))**2)
```
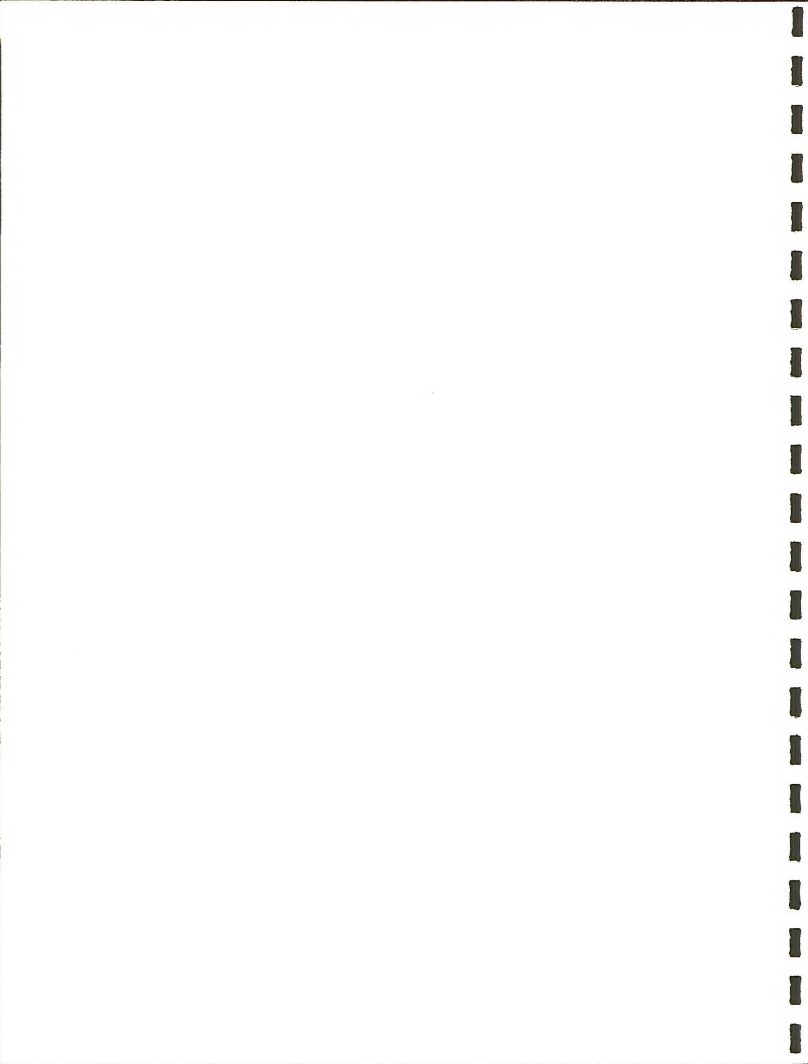
```
      SUMX1=SUMX1+XDAT1(N)
   14 CONTINUE
      DO 15 N=1,J2
      SUMX2=SUMX2+XDAT2(N)
   15 CONTINUE
C COMPUTE C
      C=(XJ1*SUMU2)-(SUMU**2)
C COMPUTE AND PRINT MEAN VALUES
      XMEA1=SUMX1/XJ1
 .    XMEA2=SUMX2/XJ2
      XVAL1=XMEA1
      XVAL2=XMEA2
      IF (XCHG.EQ.0.0) GO TO 149
      XVAL=XMEA1
      XVAL1=XMEA2
      XVAL2=XVAL
  149 XAVE1=XVAL1
      XAVE2=XVAL2
      IF(ICPT(J).NE.3HLOG) GO TO 150
      XAVE1=10.**(XAVE1)
      XAVE2=10.**(XAVE2)
  150 WRITE(6,151) LABEL(J),XAVE1
  151 FORMAT(1H0,15H MEAN VALUE OF ,A4,13H FOR SET 1 = ,F12.4)
      WRITE(6,152) LABEL(J),XAVE2
  152 FORMAT(1H0,15H MEAN VALUE OF ,A4,13H FOR SET 2 = ,F12.4)
      T=(XMEA1-XMEA2)/(SQRT(C/((XJ1**2)*(XJ1-1))))
      T=ABS(T)
      NDEGF=J1-1
      WRITE(6,109) LABEL(J),NDEGF,T
  109 FORMAT(1H0,13H T VALUE FOR ,A4,6H WITH ,I3,22H DEGREES OF FREEDOM
     1= ,F12.4)
    6 CONTINUE
    1 CONTINUE
      END
```

```
      DIMENSION IFMT(16),LABEL(22),FLAG(19),XLMT(22),DL(22),DATA(999,23)
     1,XDATA(999),IHEAD(26),IOPT(22),INUM(299)
C READ IN NUMBER OF DATA SETS, NUMBER OF ELMENTS
      READ(13,114)MM,MMM
114 FORMAT(2I2)
C READ IN ELEMENTS DETERMINED
      READ(13,127)(LABEL(I),I=1,MMM)
103 FORMAT(12A5)
C READ IN LOG OPTION
      READ(13,117)(IOPT(I),I=1,MMM)
117 FORMAT(12A3)
C READ IN FLAG FOR END OF DATA SET
      READ(13,122)(FLAG(I),I=1,MMM)
102 FORMAT(12F3.0)
C READ IN DETECTION LIMIT FOR EACH ELEMENT
      READ(13,123)(DL(I),I=1,MMM)
103 FORMAT(12F5.2 )
      FACTR=ALOG(10.)
      DO 12 M=1,MM
C READ IN HEADING FOR EACH DATA SET
      READ(13,115)(IHEAD(I),I=1,16)
115 FORMAT(16A5)
      WRITE(6,116)(IHEAD(I),I=1,16)
116 FORMAT(1H1,16A5)
      WRITE(6,127) (LABEL(I),I=1,MMM)
122     FORMAT(1X,12(5X,A5))
      N=1
C READ DATA CHECKING FOR LAST SAMPLE (CAUTION-9999MIGHT HAVE TO BE
C CHANGED FOR DATA IN A DIFFERENT FORMAT,
5       READ(8,200)INUM(N), (DATA(N,K),K=1,MMM)
      IF(INUM(N).EQ.999) GO TO 7
200 ,   FORMAT(I3,51X,F5.1,2X,F4.2//)
      WRITE(6,221) (DATA(N,K),K=1,9)
201     FORMAT(1X,10(F7.2,4X))
C COUNT DATA
      N=N+1
      GO TO 5
C BEGIN LOOP THROUGH EACH ELEMENT
7   DO 8 J=1,MMM
C SET COUNTERS AND SUMS TO ZERO
      SUMX=0.
      SUMX2=0.
      NP=0
      NT=0
      N=1
C MATCH FOR FLAG, SAMPLES BELOW DETECTION LIMIT
6   IF(DATA(N,J).EQ.FLAG(J)) GO TO 1
      IF(DATA(N,J).LT.7. ) GO TO 3
      IF (DATA(N,J).EQ.0.20) GO TO 2
      IF(IOPT(J).NE.3HLOG) GO TO 13
C CONVERT TO LOGS
      XDATA(N)=ALOG10(DATA(N,J))
      GO TO 14
13  XDATA(N)=DATA(N,J)
C SUM DATA(LOGS) AND UPDATE COUNTERS
14  SUMX=SUMX+XDATA(N)
      SUMX2=SUMX2+XDATA(N)**2
      GO TO 4
3     NP=NP+1
4     NT=NT+1
```

```
    2 NN=N+1
      GO TO 6
C CHECK TO BE SURE SOME OF THE DETERMINATIONS ARE ABOVE THE DETECTION
C LIMIT
    1 IF(NT.NE.0) GO TO 10
   11 WRITE(6,111) LABEL(J)
  111 FORMAT(1H2,33HNO ANALYTICAL DETERMINATIONS FOR ,A4,21HABOVE DETECT
     1ION LIMIT )
      GO TO 9
C DETERMINE THE NUMBER OF DETERMINATIONS ABOVE THE DETECTION LIMIT
   10 NN=NT-NP
      IF(NN.EQ.0) GO TO 11
C CONVERT NUMBER TO FLOATING POINT
      XN=FLOAT(NN)
C WRITE SUMS
      WRITE(6,112) LABEL(J),SUMX
  112 FORMAT(1H2,15HSUM(LOG) X FOR ,A4,3H = ,F12.3)
      WRITE(6,113) LABEL(J),SUMX2
  113 FORMAT(1H ,18HSUM(LOG) X**2 FOR ,A4,3H = ,F12.3)
C DETERMINE GEOMETRIC MEAN
      XMEAP=SUMX/XN
C IF LOG OPTION NOT TAKEN GO TO BRANCH
      IF(IOPT(J).NE.3HLOG) GO TO 15
      GMEAP=EXP(FACTR*XMEAP)
      WRITE(6,104) LABEL(J),GMEAP
  104 FORMAT(1H ,19HGEOMETRIC MEAN FOR ,A4,3H = ,F10.3)
C DETERMINE GEOMETRIC DEVIATION
      GDEV=EXP(FACTR*(SQRT((1./((XN**2)-XN))*(((XN*SUMX2)-(SUMX**2))))))
      WRITE(6,105) LABEL(J),GDEV
  105 FORMAT(1H ,24HGEOMETRIC DEVIATION FOR ,A4,3H = ,F10.3)
C DETERMINE SIGMA PRIME (USGS PROF. PAPER 574-B, P. 7)
      SP=SQRT((SUMX2/XN)-(XMEAP**2))
      SPP=EXP(FACTR*SP)
      WRITE(6,106) LABEL(J),SP
  106 FORMAT(1H ,16HSIGMA PRIME FOR ,A4,3H = ,F10.3)
C DETERMINE NUMBER OF SAMPLES BELOW THE DETECTION LIMIT AND PROPORTION
C ABOVE THE DETECTION LIMIT
      WRITE(6,107) NP,NT,LABEL(J)
  107 FORMAT(1H ,I3,27H SAMPLES OUT OF A TOTAL OF ,I3,
     135H ARE BELOW THE DETECTION LIMIT FOR ,A4)
      XH=FLOAT(NP)/FLOAT(NT)
      WRITE(6,108) LABEL(J),XH
  108 FORMAT(1H ,46HFRACTION OF SAMPLES BELOW DETECTION LIMIT FOR ,A4,3H
     1= ,F10.3)
C DETERMINE X-AXIS VALUE FOR ESTIMATING LAMBDA (USGS PROF. PAPER 574-B.
      XLAM=(SP**2)/((XMEAP-ALOG10(DL(J)))**2)
      WRITE(6,110) LABEL(J),XLAM
  110 FORMAT(1H ,42HVALUE OF X-AXIS FOR ESTIMATING LAMBDA FOR ,A4,3H = ,
     1F10.3)
      GO TO 9
C WRITE ARITHMETIC MEAN
   15 WRITE(6,118) LABEL(J),XMEAP
  118 FORMAT(1H ,27HARITHMETIC MEAN FOR ,A4,3H = ,F10.3)
C COMPUTE STANDARD DEVIATION
      STDEV=SQRT((1./((XN**2)-XN))*(((XN*SUMX2)-(SUMX**2))))
      WRITE(6,119) LABEL(J),STDEV
  119 FORMAT(1H ,23HSTANDARD DEVIATION FOR ,A4,3H = ,F12.3)
      SP=SQRT((SUMX2/XN)-(XMEAP**2))
      WRITE(6,106) LABEL(J),SP
      WRITE(6,107) NP,NT,LABEL(J)
```

```
      WRITE(6,128) LABEL(J),XH
C COMPUTE X-AXIS VALUE FOR ESTIMATING LAMBDA
      XLAM=(SP**2)/((X*EAP-DL(J))**2)
      WRITE(6,112) LABEL(J),XLAM
    8 CONTINUE
   12 CONTINUE
      END
```

Figure 6. Plot of Analysis of Variance
Sample Locations.

PLOT NUM	SAMP NUM	LAT.	LON.	HG	Z	LI	ORG-C	PH	MOSG	G SG	B	MO
1	101	395914.	1282472.	-20.	52.	14.	.42	8.2	.93	27.2	161.3	1.80
2	102	395916.	1282473.	72.	45.	17.	1.72	8.2	.36	28.2	162.3	1.43
3	103	395922.	1282334.	83.	65.	17.	.64	7.1	.33	25.2	130.3	.83
4	104	395924.	1282371.	63.	42.	17.	.76	7.2	.61	32.2	123.3	1.93
5	106	395922.	1282313.	64.	59.	15.	.74	7.7	.53	28.2	139.3	1.83
6	107	395916.	1282312.	59.	62.	15.	.46	7.8	.93	23.2	143.3	1.13
7	108	395915.	1282316.	51.	46.	12.	.45	7.3	.75	27.2	126.3	2.03
8	109	395915.	1282316.	64.	61.	15.	.53	7.5	.76	24.2	98.9	1.43
9	270	395714.	1282812.	64.	59.	22.	1.62	7.9	.43	28.2	125.3	1.13
13	271	395712.	1282829.	83.	63.	21.	1.23	7.3	.96	32.2	201.3	2.13
11	272	395711.	1282733.	35.	36.	15.	1.93	7.7	.31	3.2	89.3	1.23
12	273	395712.	1282728.	49.	41.	12.	1.13	7.4	.74	38.7	86.1	1.53
13	280	395627.	1282728.	31.	73.	21.	1.33	7.7	.83	28.2	189.3	3.03
14	281	395624.	1282733.	95.	77.	21.	1.23	7.7	1.00	33.2	293.3	3.03
15	282	395732.	1282733.	38.	49.	17.	.83	7.4	.37	32.2	137.3	1.53
16	283	395732.	1282731.	57.	61.	12.	.27	7.9	.52	39.2	63.7	2.73
17	322	395335.	1282916.	81.	75.	22.	.63	7.8	1.23	33.7	133.3	2.83
18	323	395431.	1282915.	85.	66.	21.	1.23	7.4	1.13	37.2	152.3	2.13
19	324	395431.	1282913.	55.	51.	24.	1.23	7.2	1.33	59.2	132.3	2.83
97												
23	325	395335.	1283033.	56.	72.	19.	1.43	8.1	.46	29.1	168.3	1.53
93												
21	333	395425.	1282929.	53.	63.	77.	1.43	8.2	2.33	35.2	112.3	4.73
93												
22	331	395427.	1282911.	49.	72.	47.	.81	8.3	1.32	34.2	145.3	5.23
93												
23	332	395419.	1282971.	85.	45.	16.	3.13	7.9	.91	33.2	141.3	.73
93												
24	333	395421.	1282903.	62.	5.	17.	2.73	7.4	.85	32.3	96.2	1.51
88												
25	416	395627.	1283112.	59.	63.	18.	1.73	7.7	.53	26.2	176.3	1.43
88												
26	417	395624.	1283129.	36.	57.	22.	1.78	7.5	.53	26.2	172.3	1.53
98												
27	418	395631.	1283137.	54.	75.	25.	2.73	7.3	.36	37.2	126.3	2.83
93												
28	419	395632.	1283134.	87.	66.	31.	1.62	7.5	.77	31.2	147.3	4.83
93												
29	422	395422.	1283179.	72.	66.	21.	2.13	7.4	.95	37.2	148.3	1.93
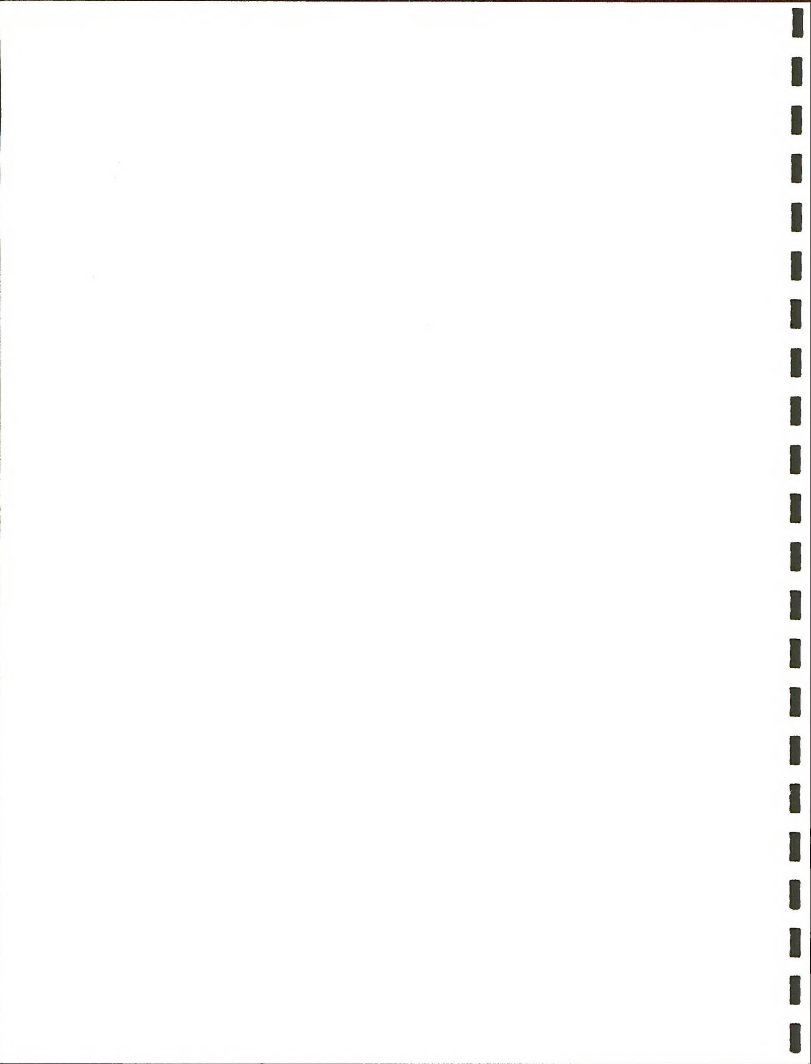
33	423	375424.	1283132.	91.	71.	27.	1.33	7.1	.50	39.2	163.3	2.03
31	424	395428.	1287206.	48.	57.	16.	2.63	7.5	1.43	37.2	133.3	2.33
32	425	395626.	1383239.	96.	64.	17.	2.63	7.6	1.23	34.2	88.9	1.93

Table 20. Analysis of Variance Data
for Components not Analyzed on the
Grid Samples.

SAMP NUM	SG ZN	RG HG	WG HG	RG ZN	WG ZN	WG B	WS MG	RG B	RG MO	SOIL AS
121	3	29		2				11	.75	6
122	2							11	.39	6
123	2							8	.83	6
124	3	32		2				12	.93	7
126	2	43		2				9	1.5	8
127	1	31		10				8	.69	6
128	5	33		9				11	.68	6
129	4							7	.73	4
270	5	-20	34	7	9	5	.89	10	1.3	7
271	3	23	23	2	11	17	1.1	10	1.0	9
272	5	.22		1				13		8
273	4	-20		7		25	.47	14	1.1	6
280	3	28	47	1	7	15	1.1	9	1.5	6
281	3	34	29	2	12	24	1.7	16	1.1	8
282	2	-20	137	11	9	15	.83	11	1.1	9
283	8	34	23	.4	11	13	1.3	8	.83	7
323	5	44	47	2	9	11	1.4	13	1.4	17
324	4	34	29	1	8	13	1.4	9	1.4	10
326	3	-20	21	11	7	17	.76	27	.93	8
327	2	24	29	4	9	16	.75	16	1.2	8
330	7	-20	39	3	14	18	1.6	9	2.0	16
331	.3	21	-20	4	11	-	1.4	11	1.4	14
332	2	46	-20	1	13	15	.68	11	1.2	6
333	2	-20	52	11	6	12	1.2	12	.70	7
416	.4	-20	-20	10	15	13		15	.88	12
417	4	21	-20	1	11	15	.83	11	.79	12
418	5	-20	-20	2	7	16	1.3	6.7	1.5	11
419	3	-20	-20	6	14	15	1.2	6.7	1.5	15
422	3	26	50	2	8	22	1.7	9.3	1.4	12
423	1	24	43	1	10	17	1.5	9.3	.77	13
424	2	-20	-20	9	4	17	1.5	9.3	1.1	11
425	.3	43	-23	2	11	14	1.1	8	.70	12
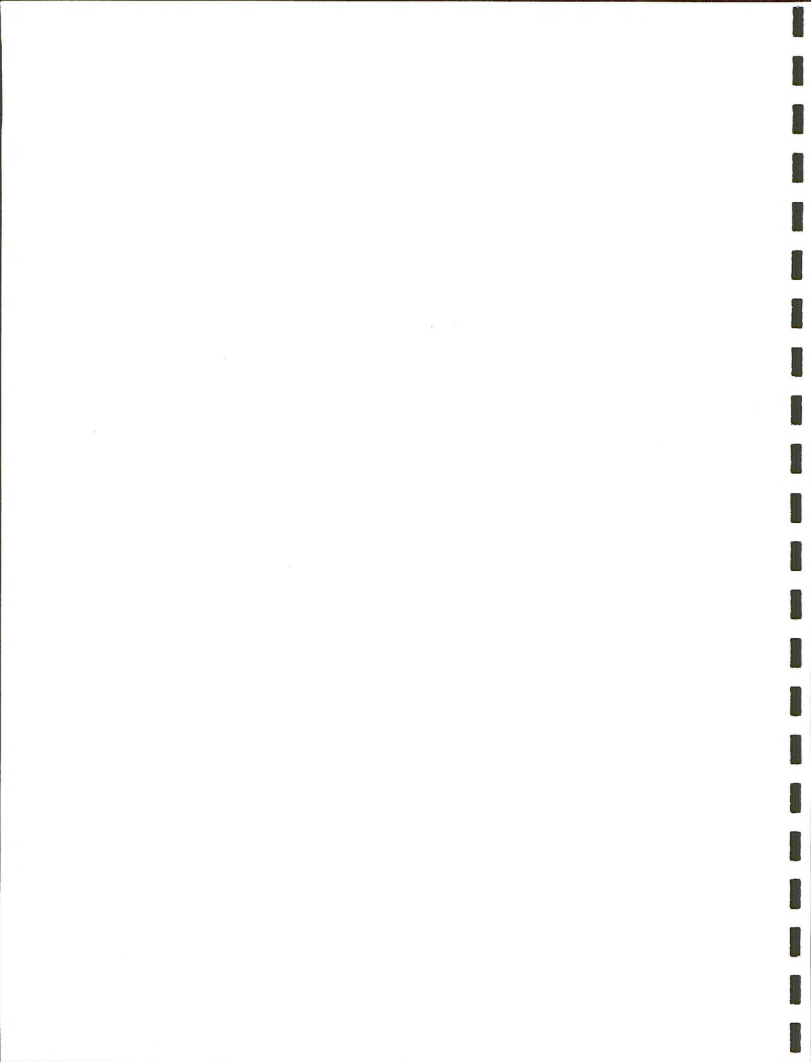
PLOT OF TRACT C-A GRID SAMPLE

LATITUDE

LONGITUDE

Figure 5. Plot of Grid Sample Locations.

Table 21. Data from Grid Samples.
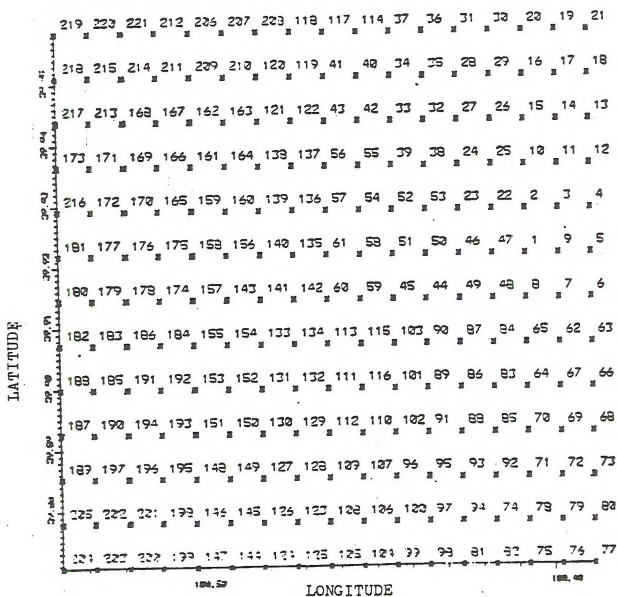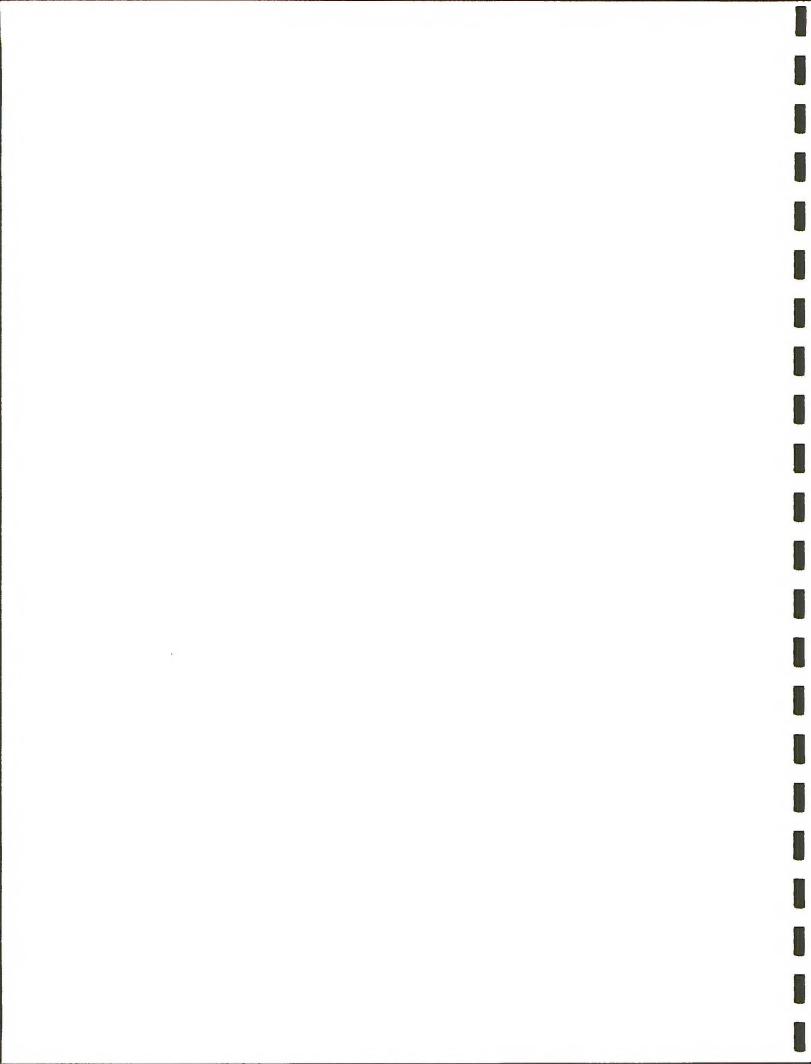
PLOT NUM.	SAMP. NUM.	LAT.	LON.	HG PPB	ZN PPM	LI PPM	ORGC %	PH	MOSG PPM	USG PPM	B PPM	MO PPM
1	100	395511.	1382415.	47.	82.	21.	.69	8.2	.63	35.6	148.2	1.12
2	111	395526.	1382415.	74.	57.	14.	.50	7.9	.53	31.3	124.2	1.32
3	112	395526.	1382331.	127.	55.	13.	.65	7.9	.64	31.5	113.2	1.52
4	113	395526.	1382311.	37.	57.	14.	.53	7.9	.83	32.5	119.2	1.52
5	114	395511.	1382311.	49.	263.	13.	.46	7.9	.83	15.7	132.2	1.52
6	115	395431.	1382311.	39.	52.	13.	1.13	7.6	.42	19.4	97.1	1.12
7	116	395431.	1382331.	45.	84.	21.	1.33	8.2	.85	25.3	136.2	1.72
8	117	395431.	1382415.	-27.	62.	15.	1.33	8.2	.63	29.2	118.2	1.32
9	118	395511.	1382331.	42.	81.	16.	.65	8.2	.03	36.1	151.2	1.92
10	119	395636.	1382415.	-23.	73.	16.	1.13	8.2	.36	26.7	176.2	1.12
11	120	395636.	1382331.	-22.	71.	17.	.66	8.1	.84	26.3	115.2	1.42
12	121	395636.	1382311.	85.	62.	15.	.65	8.1	.46	35.7	136.2	1.52
13	123	395622.	1382311.	34.	62.	14.	.65	7.9	.73	33.6	127.2	1.82
14	124	395622.	1382331.	79.	66.	15.	1.23	7.9	.46	33.6	141.2	1.08
15	126	395622.	1382415.	22.	67.	19.	1.92	8.3	.87	32.1	148.2	.83
16	127	395722.	1382415.	36.	66.	17.	.73	8.3	.79	31.7	162.2	2.22
17	128	395722.	1382331.	23.	112.	13.	1.23	8.2	.47	29.5	118.2	1.42
18	129	395722.	1382311.	24.	61.	16.	1.13	8.1	.67	23.7	119.2	1.52
19	134	395717.	1382331.	25.	79.	24.	2.43	8.1	.55	29.9	125.2	1.62
20	135	395717.	1382415.	32.	223.	16.	.69	8.2	.83	34.3	88.2	1.52
21	136	395717.	1382311.	59.	82.	19.	1.33	8.3	.36	42.9	137.2	.75
22	139	395526.	1382435.	-27.	53.	13.	.77	8.1	.66	27.5	86.1	2.23
23	140	395526.	1382519.	-23.	67.	23.	1.13	8.3	.44	22.7	152.2	1.03
24	143	395634.	1382519.	24.	114.	16.	.88	8.1	1.33	33.7	59.0	.83
25	144	395636.	1382435.	-23.	33.	14.	.25	8.3	1.53	35.6	123.2	1.52
26	145	395622.	1382435.	-23.	72.	17.	.93	8.1	.33	28.4	117.2	1.12
27	146	395622.	1382519.	35.	72.	19.	1.93	8.2	.46	22.4	112.2	1.23
28	147	395722.	1382519.	-23.	64.	17.	.57	9.1	.63	19.7	144.2	1.83
29	148	395722.	1382435.	24.	73.	23.	.81	7.4	.42	28.3	41.3	1.12

```
30  149  395717. 1282435. -20.  62. 14.  .85 8.1  .67 28.8 128.2  .80
31  152  395717. 1282519.  47.  91. 23. 1.30 8.2  .77 29.0 163.2 1.50
32  151  395622. 1282623.  88.  64. 18.  .88 8.1  .67 23.2 132.2 2.00
33  152  395622. 1282623.  47.  94. 18.  .65 8.1  .59 25.4  47.4  .90
34  153  395732. 1382623.  33. 133. 22. 1.70 7.9  .37 22.7  99.2 1.20
35  154  395732. 1382623.  23.  90. 20.  .66 8.2  .83 32.4 146.2 1.30
36  155  395717. 1032623.  34.  82. 25. 1.30 7.9  .65 32.0 129.2 1.40
37  156  395717. 1382623.  29.  53. 16.  .89 8.0  .31 27.5  54.4 1.10
38  159  395426. 1382633. -20.  35. 14.  .68 8.3  .90 34.1 134.2  .80
39  161  395626. 1282623. -23.  59. 15.  .86 8.2 1.10 33.5  93.5 1.20
40  165  395732. 1282728.  24.  75. 20.  .75 8.2  .78 38.2 161.2 2.10
41  166  395732. 1282728. -20.  66. 17. 1.20 7.9  .68 30.5  86.1 1.10
42  169  395622. 1282728. -20.  31. 15. 1.20 8.3  .41 34.1 111.2 1.70
43  173  395622. 1282728. -20. 235. 21. 1.20 8.2  .45 34.5 143.2 1.20
44  171  395431. 1282623.  48.  46. 16. 1.50 7.9  .55 27.3  93.4  .50
45  174  395431. 1282623.  35.  72. 19. 1.20 8.2  .57 28.7 133.2 1.10
46  175  395511. 1382519.  88.  72. 15. 1.90 8.0  .47 24.4 128.2 1.20
47  177  395511. 1282435.  50.  78. 17. 1.60 7.9  .42 26.0 131.2 1.80
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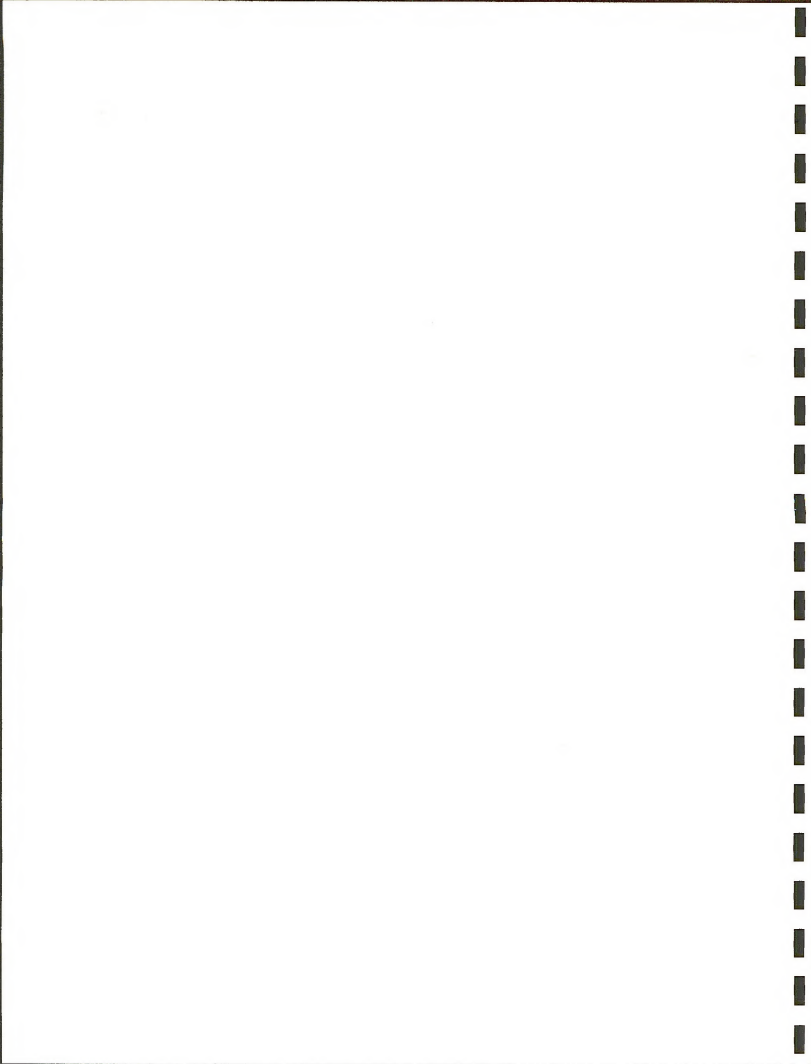
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62 (2)	201	395415.	1382331.	64.	67.	23.	1.02	7.2	2.50	24.3	113.0	1.70
63 (2)	202	395415.	1382311.	22.	72.	21.	.74	8.1	.33	31.6	128.0	1.10
54 (2)	203	395335.	1382415.	115.	233.	15.	1.20	7.4	.55	41.4	91.6	1.70
65 (0)	204	395415.	1382415.	-20.	65.	16.	1.22	7.9	.90	29.6	128.0	1.30
66 (2)	205	395335.	1382311.	-22.	44.	15.	1.30	8.1	.56	30.3	132.0	1.10
67 (2)	206	395335.	1382331.	61.	53.	15.	1.10	8.0	.89	36.5	98.0	1.30
68 (2)	207	395319.	1382311.	23.	73.	17.	.89	8.2	.31	28.1	143.0	1.30
69 (2)	208	395319.	1382331.	65.	61.	23.	1.30	7.2	.60	29.5	155.0	1.20
70 (2)	209	395319.	1382415.	47.	71.	18.	1.40	7.6	.44	24.3	91.6	1.20
71 (0)	210	395323.	1382415.	39.	72.	15.	.97	8.2	.52	25.9	123.0	1.40
72 (0)	212	395323.	1382331.	60.	78.	21.	1.30	8.1	1.00	28.0	124.0	2.20
73 (0)	213	395323.	1382311.	34.	48.	18.	1.70	8.0	1.10	36.5	103.0	2.10
74 (2)	217	395224.	1382435.	36.	82.	18.	.84	8.2	1.30	25.8	132.0	1.30
75 (90)	218	395228.	1382415.	19.	79.	22.	1.10	7.9	1.20	28.2	115.0	5.70
76 (0)	219	395228.	1382331.	67.	76.	22.	1.30	7.4	1.10	41.1	122.0	2.50
77 (0)	220	395208.	1382311.	27.	79.	19.	1.40	8.0	.73	27.7	124.0	1.70
78 (90)	221	395224.	1382415.	15.	75.	16.	.63	8.1	.48	25.7	154.0	1.20
79 (90)	222	395224.	1382331.	45.	61.	22.	2.20	7.8	.66	32.8	134.0	1.40
80 (0)	223	395224.	1382311.	42.	72.	23.	2.20	7.8	.52	28.0	128.0	1.70
81 (2)	224	395228.	1382519.	46.	80.	17.	.60	8.2	1.10	36.5	129.0	1.20
82 (0)	225	395228.	1382435.	29.	176.	19.	.96	7.8	.40	24.4	99.0	1.40
83 (0)	228	395335.	1382435.	39.	71.	17.	1.20	7.5	.83	31.3	148.0	1.10
84 (0)	231	395415.	1382435.	46.	65.	17.	1.10	8.1	.69	30.3	128.0	1.30
85 (2)	232	395319.	1382435.	57.	83.	16.	.98	7.9	.78	28.0	150.0	1.30
86 (0)	235	395335.	1382519.	38.	78.	14.	1.00	8.2	.87	36.7	139.0	.80
87 (0)	236	395415.	1382519.	46.	68.	13.	.25	8.3	.00	34.0	104.0	1.80
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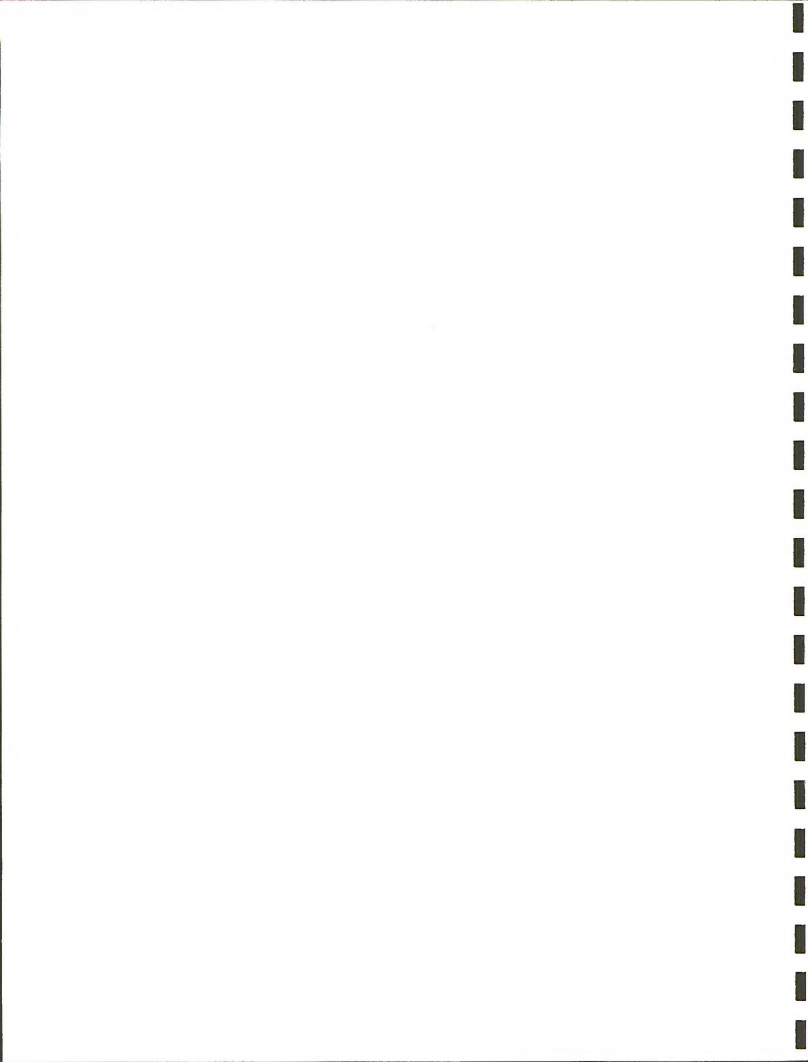
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93	242	395303.	1382519.	24.	67.	16.	.73	8.2	.46	25.8	123.0	1.20
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114	265	395717.	1382708.	46.	58.	22.	1.20	8.1	.00	22.3	129.0	1.10
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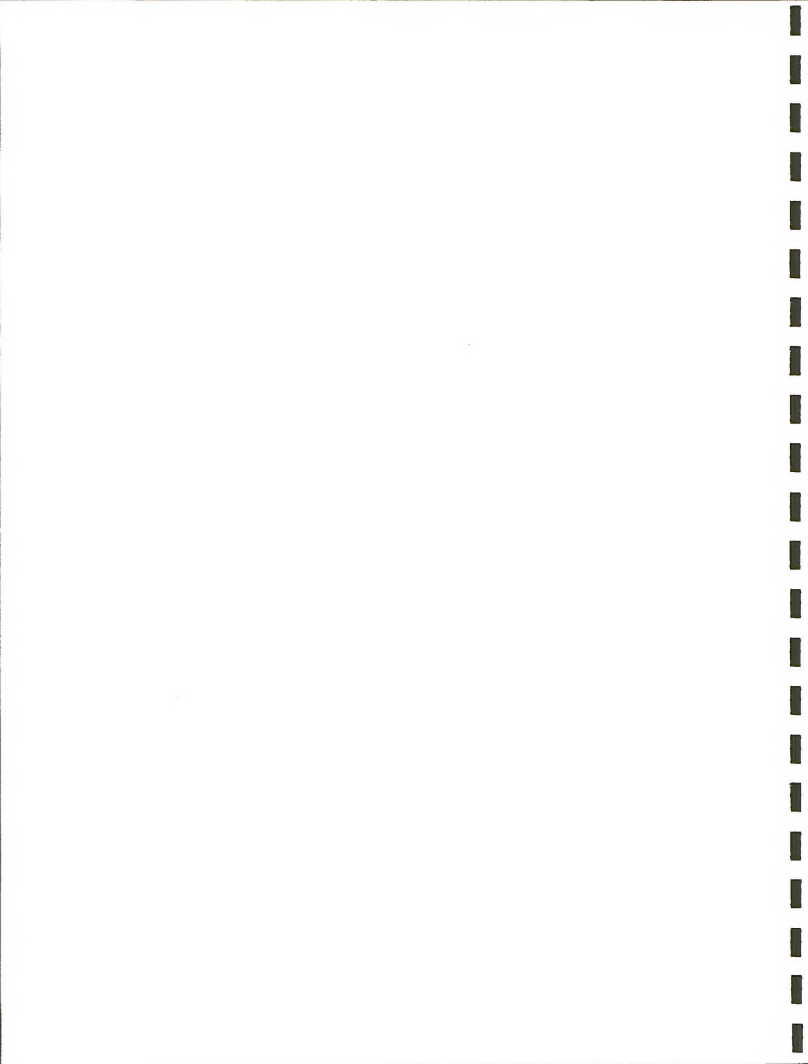
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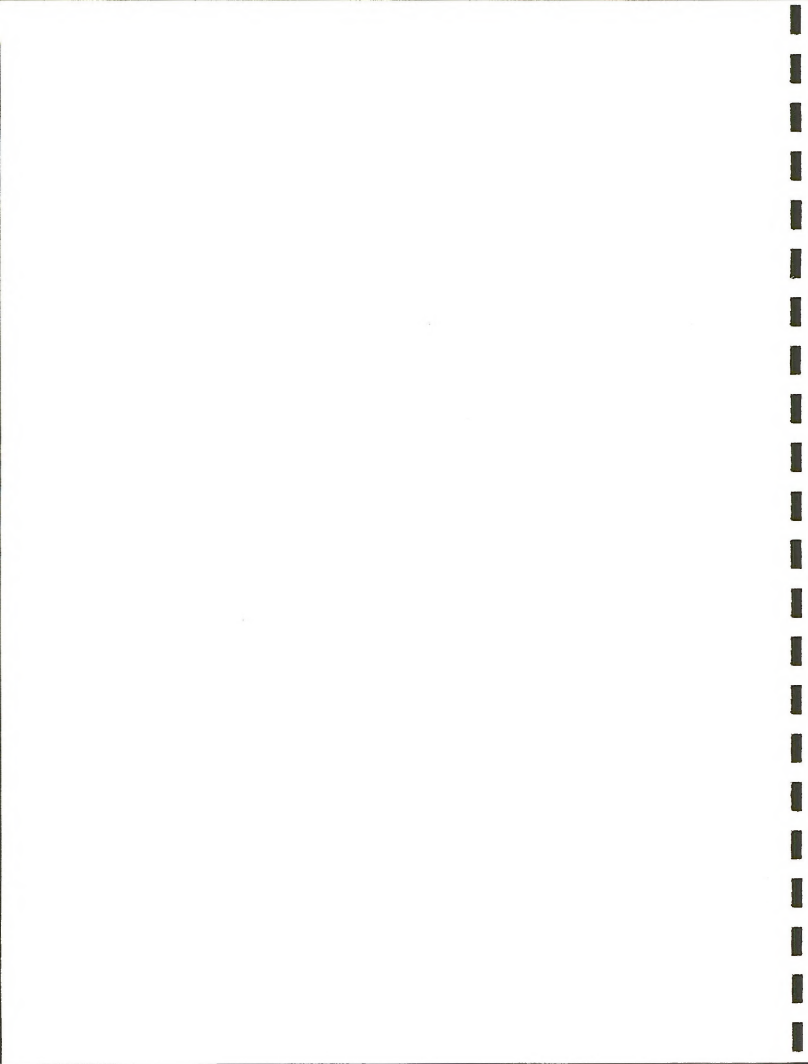
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8 188	384	395335.	1383209.	41.	67.	29.	1.60	7.1	.38	30.7	126.0	1.70
98 189	385	395303.	1383209.	-23.	77.	53.	1.60	7.8	2.50	29.6	99.0	3.60
98 190	388	395319.	1383124.	52.	76.	59.	2.30	8.0	.89	26.3	154.0	4.20
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0 199	398	395208.	1383020.	85.	70.	15.	1.80	7.6	1.90	28.7	130.0	1.50
8 200	399	395208.	1383124.	79.	73.	15.	1.00	7.4	.46	35.1	89.8	1.30
8 201	400	395224.	1383104.	39.	66.	14.	.74	8.2	.27	26.5	129.0	.40
2 202	401	395224.	1383124.	46.	69.	13.	1.40	8.1	.55	28.7	82.9	1.10
8 203	402	395208.	1383124.	118.	66.	19.	1.40	7.8	.45	28.5	99.0	1.10
0 204	403	395208.	1383209.	30.	59.	20.	1.40	7.3	.43	23.8	161.0	1.00
0 205	404	395224.	1383279.	131.	89.	19.	1.20	7.3	.00	29.6	139.0	1.50
8 206	405	395717.	1383002.	46.	77.	14.	1.50	8.0	1.20	30.0	86.1	.80
8 207	406	395717.	1382916.	35.	65.	12.	.43	8.0	.49	30.0	110.0	1.20
2 208	407	395717.	1382832.	56.	67.	14.	1.60	8.1	.57	42.3	117.0	.42
8 209	408	395702.	1383020.	22.	79.	15.	1.10	7.7	.38	29.6	134.0	1.60

```
     8
212   411   395732. 1382916.   37. 163.   15.  .63  8.3  .55  32.5  124.2   .72
     8
211   412   395722. 1383023.  -23.  66.   15.  .86  7.9  .41  34.1  132.2  1.10
     8
212   413   395717. 1383023.   56.  89.   14. 1.10  7.5  .53  37.6   48.2  1.10
213   414   395622. 1383124.   93.  77.   37. 2.03  8.3 1.33  24.9  187.2  2.33
     98
214   415   395732. 1383124.   62.  72.   33. 3.33  8.1  .64  36.3  138.2  2.23
     93
215   423   395732. 1383124.   53.  55.   33. 2.33  8.1  .74  42.4  124.2  2.33
     3
216   421   395526. 1383223.   23.  72.   19.  .75  8.2  .78  36.7  132.2  2.63
     90
217   426   395622. 1383223.   25.  66.   24. 2.33  7.8  .45  24.8  114.2  2.83
     90
218   427   395732. 1383273.   26.  61.   34. 2.23  8.1  .82  35.9  128.2  4.13
     8
219   428   395717. 1383223.   37.  73.   14. 1.63  7.9  .43  28.9  126.2  1.53
     90
222   429   395717. 1383124.   24.  65.   59. 1.23  8.2 1.43  26.8  152.2  1.23
     92
221   433   395717. 1383124.   62.  81.   56. 2.53  8.1 1.53  33.3  112.2  3.93
```
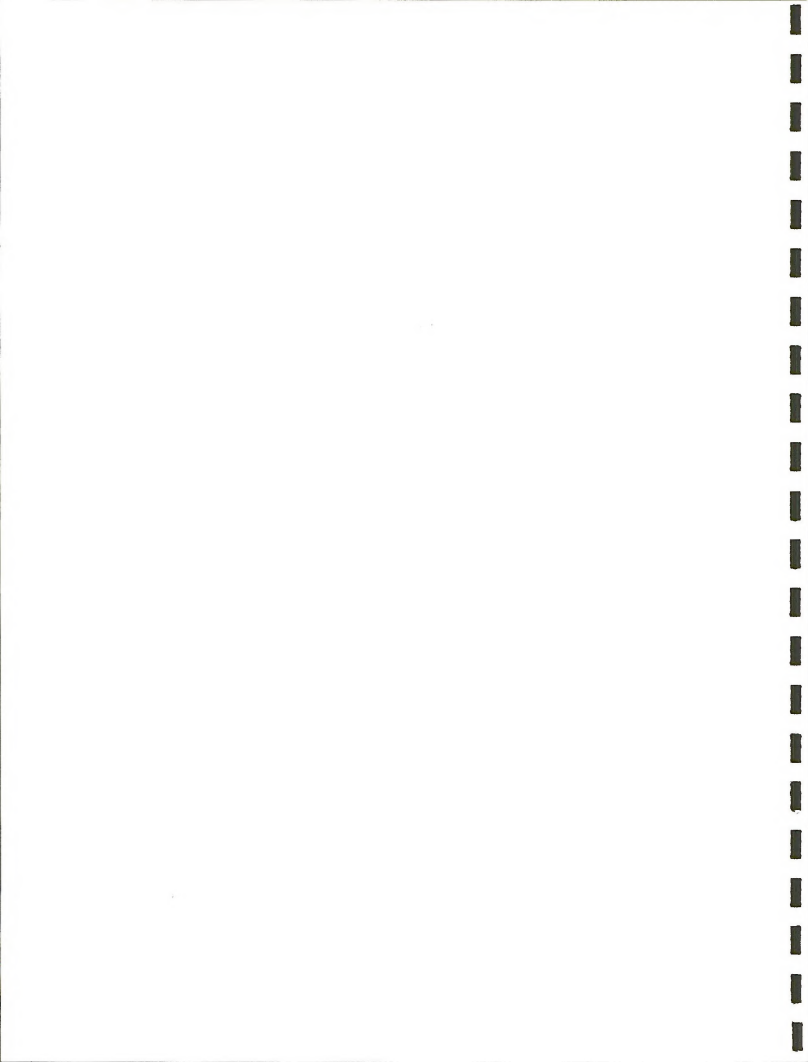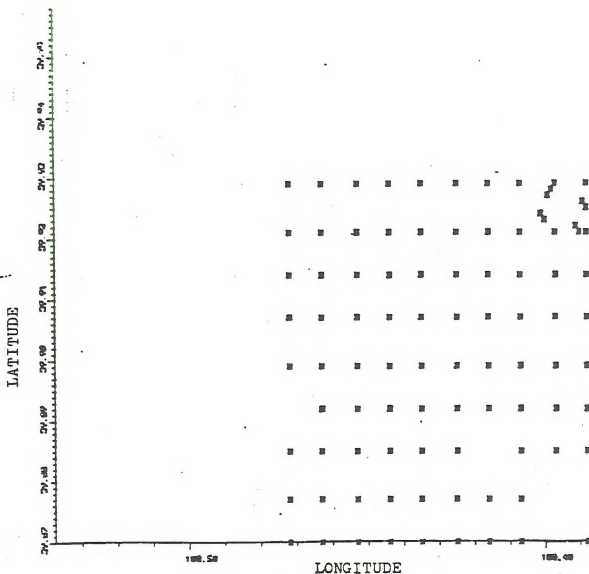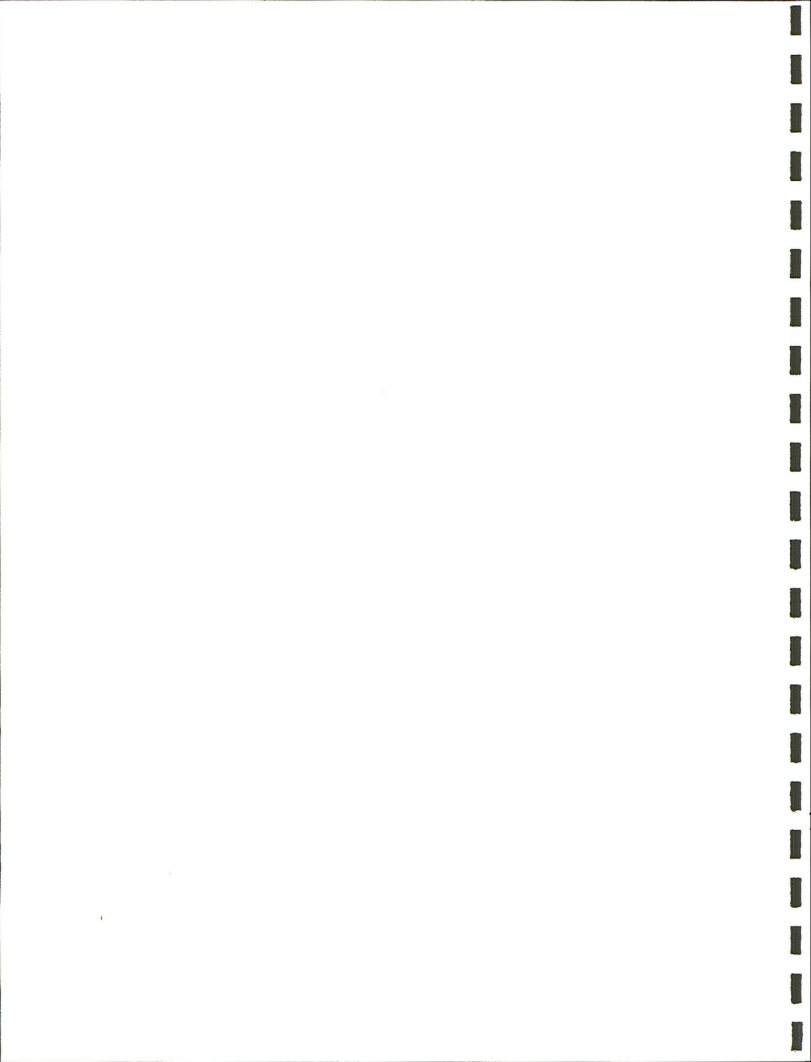
PLOT OF GROUP 1 UINTA FORM.

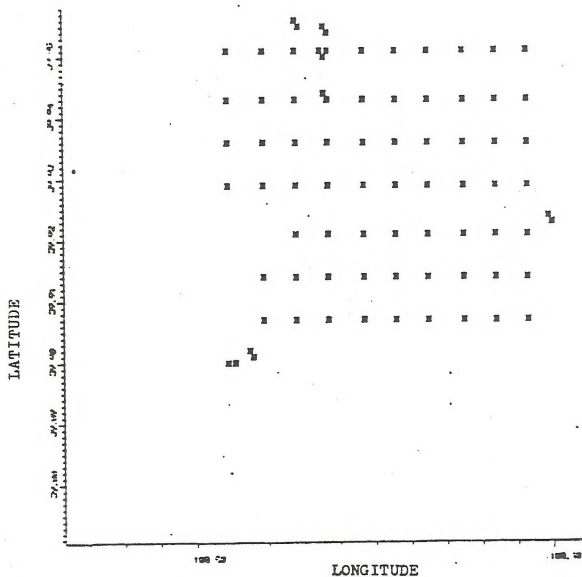Figure 18. Plot of Group 1 Uinta Formation
Sample Locations.

PLOT OF GRP2 UINTA FORM.

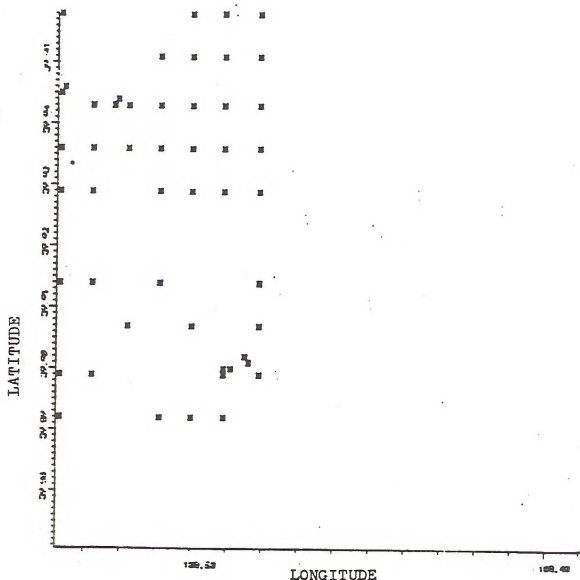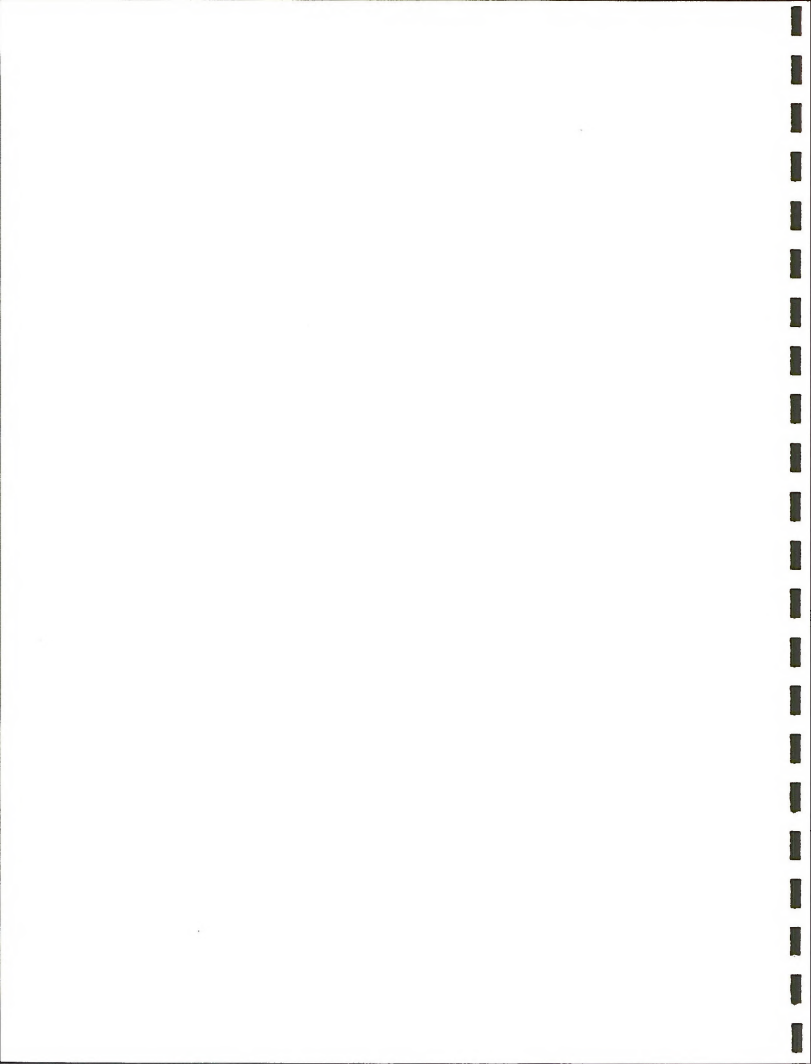Figure 19. Plot of Group 2 Uinta Formation
Sample Locations.

PLOT OF GROUP 3 UINTA FORM.

LATITUDE

LONGITUDE

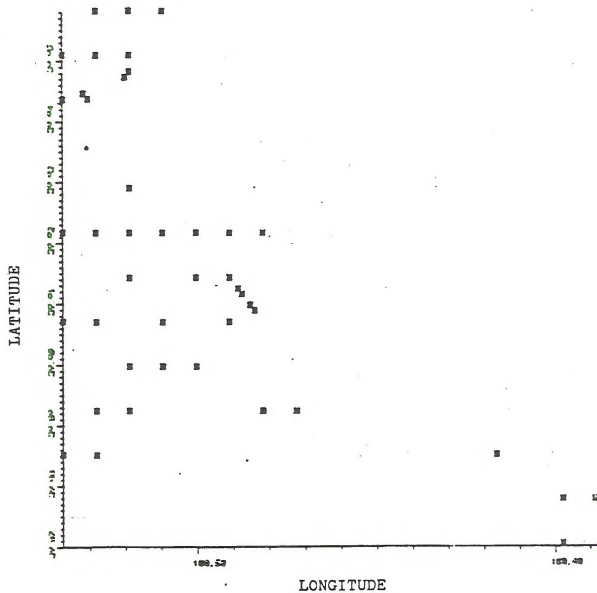Figure 20. Plot of Group 3 Uinta Formation
Sample Locations.

Figure 21. Plot of Group 4 Parachute Creek member Sample Locations.

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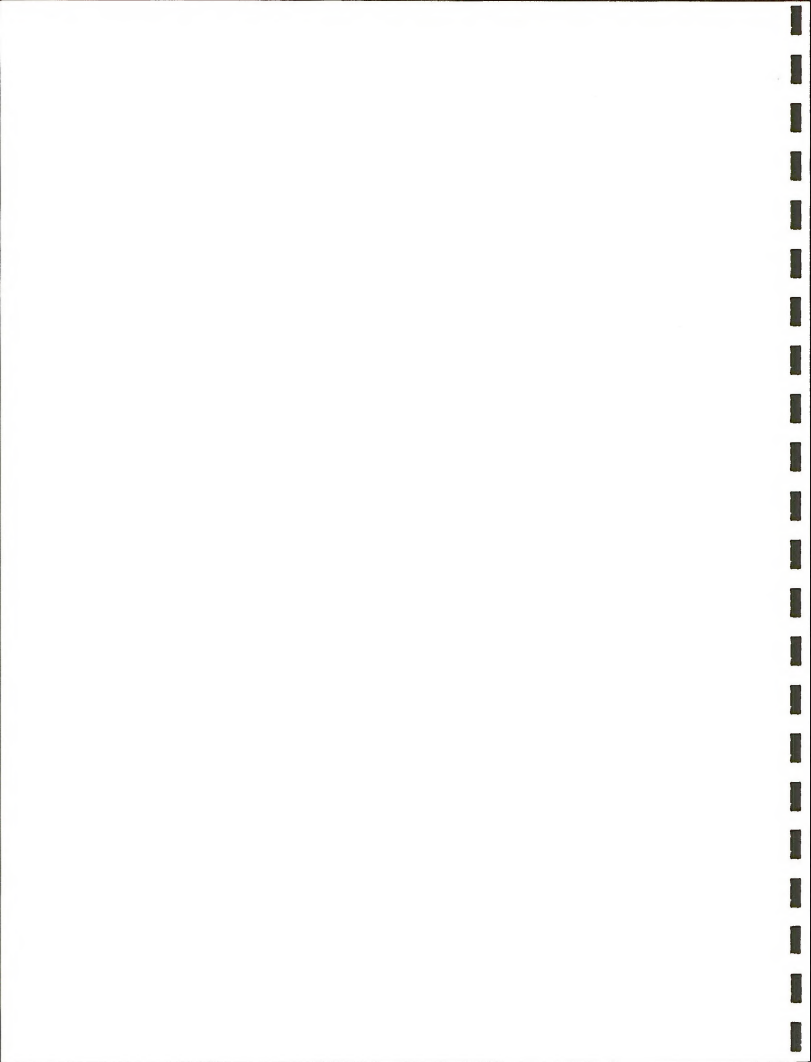
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